NYASALAND PROTECTORATE

REPORT ON

Some Diseases of Tea and Tobacco in Nyasaland

By E. J. BUTLER, C.I.E., D.Sc., F.R.S., *Director, Imperial Bureau of Mycology*

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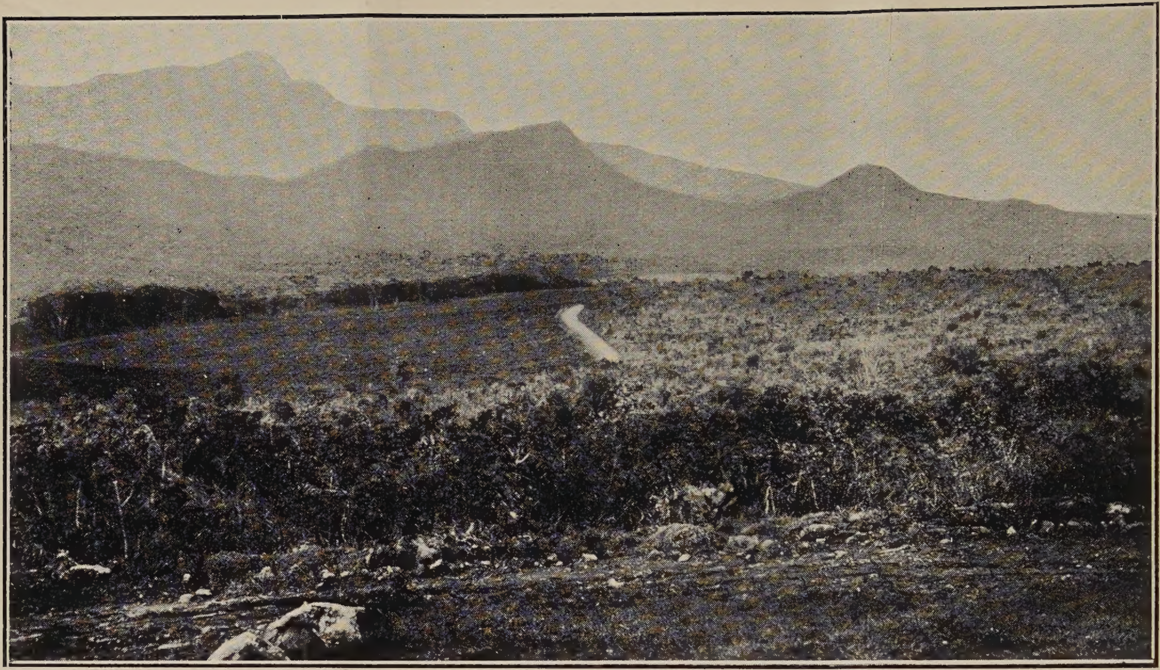

Fig. 1.—View from Suruku Bungalow, Lauderdale.

Fig. 2.—Chitakali.

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INTRODUCTION.

The following notes are the outcome of a visit to Nyasaland between the 15th February and 31st March, 1927. This visit was undertaken at the request of the Nyasaland Government, mainly as a result of representations made on behalf of the tea planters in the Protectorate. It was natural, therefore, that most attention was given to the difficulties experienced in several estates in securing a full crop owing to the injuries caused by diseases of the tea bush, and the greater part of these notes refer to this matter. As much work as possible was done on these diseases on the spot and material was brought back to England for further study. A little time was available for observations on the chief diseases of the tobacco crop that were to be found during the period of my visit. These, however, were ascertained to be essentially similar to those occurring in Rhodesia and South Africa, where they have been the subject of considerable study, and there does not appear to be the same need for local investigation of tobacco diseases, in spite of the importance of the crop, that there is in the case of tea, in regard to which practically no work has been done in southern or eastern Africa. One tobacco disease, however, was found which had not previously been recorded in this area, and a somewhat detailed account of this is given.

The visit was timed to coincide with the rainy season, when it was hoped that disease processes would be showing their greatest activity. In general this hope was probably fulfilled, but I was unfortunate in not finding a severe attack of the tea canker attributed to *Macrophoma theæ*, either because some seasonal factors had diminished its activities or the measures undertaken the previous year on the advice of the Nyasaland Agricultural Department had effectively checked its spread. As this appears to be one of the diseases peculiar to Nyasaland the scanty opportunities for its study were regrettable.

The possibilities of tea cultivation in various parts of east and central Africa are at present attracting a good deal of attention. In the older tea countries of the East, extension is limited by scarcity of new suitable districts, insufficient labour, and the competition of other plantation crops. In Africa good land is abundant and other difficulties are not such as cannot be overcome. The Nyasaland tea industry is the only one of appreciable importance as yet, and its fate will be watched with interest by neighbouring colonies. Coffee was wiped out in the Protectorate by the depredations of insect pests. The cotton area is declining, and unless some method of controlling boll worms is found, they will prevent the extensive development of this important crop in a region that is otherwise very well suited for its growth. In the same way, the small but promising tea industry might well become unprofitable owing to the unusual prevalence of certain types of disease, but all of these, save one, are, I believe, susceptible to fairly ready control—and the one exception is, perhaps, only formidable because its origin is as yet unknown.

As there has been some little controversy about the earliest introduction of the tea bush into cultivation in Nyasaland, the following details may be of interest. The earliest attempt to introduce coffee and tea that I have been able to trace was in 1878, when plants of both species were brought out from the Royal Botanic Garden, Edinburgh (the Regius Keeper of which at that time was John Hutton Balfour) by Mr. Jonathan Duncan, a gardener of the Blantyre Mission of the Church of Scotland. All these died except one coffee plant, from which 400 seedlings were raised and these yielded 14½ cwt. of coffee in 1883. By 1891 the coffee industry was firmly established in the Mlanje district, and in 1901 the area under the crop was nearly 17,000 acres, but by 1925 it had fallen to 857, mainly as a result of an unsuccessful fight against insect pests. In 1888 a further attempt was made to introduce tea, Dr. Elmslie of the Livingstonia Mission of the Free Church of Scotland taking out plants in a Wardian case from the Edinburgh Botanic Garden, to the Keepership of which Isaac Bayley Balfour had just succeeded. These plants were handed over to Mr. Duncan at the Blantyre Mission Garden, where two survived and one is still to be seen. Seed from these early plants was taken to Lauderdale and Thornwood Coffee Estates in Mlanje, in one of which it was being planted in 1891, apparently by Mr. Henry Brown. In 1895 Mr. Alexander Whyte reported at the request of Commissioner (afterwards Sir Harry) Johnston and of the Royal Botanic Gardens, Kew, that "Tea of good varieties, Assam and China, has been introduced, but it is not yet cultivated to any extent. It grows luxuriantly and ought to do well

in some districts. . . . . I see no reason why it should not become a profitable cultivation." It is certain that Mr. Brown was responsible for the extensive early planting at Thornwood Estate, samples of manufactured tea from which, received for report in 1898, are preserved in the Museum at Kew Gardens. In 1904 there were over 200 acres under tea at Thornwood and 50 at Lauderdale, and in 1908 about 600 acres were planted and tea first figured in the Nyasaland exports. Subsequent introductions were in part, unfortunately, from Natal, whence varieties of low quality appear to have been derived. It is only of comparatively recent years that an attempt has been made to improve quality by the introduction of high class Indian seed, and most estates still show an excessively mixed population of bushes.

In the identification of Nyasaland tea diseases valuable pioneering work has already been done by Captain C. Smee, the Entomologist to the Department of Agriculture, and he and Mr. E. W. Davy, the Assistant Director, have had considerable success in getting an effective control of certain diseases, such as canker. Capt. Smee gave me invaluable assistance during my visit, the arrangements for which were made by Mr. E. J. Wortley, Director of Agriculture, without whom I would have been helpless. To these and the other members of the Agricultural Department in Nyasaland, my warmest thanks are due. I also received abundant hospitality and aid from members of the planting community, particularly from Mr. A. E. Shinn of the Ruo Estates, Ltd., and the Hon. W. Tait-Bowie and Mr. W. Morris Scott of the Blantyre and East Africa Co., Ltd., which I desire gratefully to acknowledge.

1. Diseases of Tea in Nyasaland.

The main tea district of Nyasaland extends from south-east to south-west along the foot of Mlanje mountain, for a distance of about twenty miles, at an elevation averaging 2,500 ft. above sea level. It rises from the Shiré Highlands, a wide and extensive plateau, on the south-eastern corner of which Mlanje is situated. The rainfall varies from about 70 to 90 inches, diminishing as the western extremity of the district is approached and also as the ground falls away from the mountain towards the plain: in general it is greater the nearer the mountain face is approached. In the western half of its extent the main mass of the mountain rises abruptly from a moderate to steep slope at its base. Towards the south-east, however, the ground is more broken by foot-hills and valleys. In both areas tea can be grown up to the steeper slopes which extend along the base of the cliffs that form the greater part of the 6,000 to 9,900 ft. to which the mass rises above sea level. These cliffs form almost vertical scarps, 4,000 to 5,000 ft. in height, along the southern and western faces of the mountain. Away from the mountain tea is found only to a distance of a few miles towards the plain. The rainfall is the limiting factor to extension both in the length and breadth of the Mlanje tea district, except to the east where the Portuguese frontier intervenes. (Figs 1 & 2.)

Several permanent rivers and streams traverse this area from the mountain towards the plain, and in the rainy season the cliffs are seamed with dozens of waterfalls owing to the very high precipitation on the upper levels of the mountain. The Great and Little Ruo falls, the former some 800 ft. in height, carry permanent streams that unite towards the Portuguese border to form the Ruo river, one of the main rivers of southern Nyasaland.

Practically the whole of this area was within recent times clothed with virgin forest, mostly of medium or small trees but reaching a good size along the streams. In a few cases the tea gardens have been cleared from grassy slopes with scattered trees, but most of those now in bearing were till recently fairly dense forest, and this is, no doubt, the explanation of the particular types of disease most prevalent in the tea. Some of the existing gardens were originally cleared for coffee planting, but even in these cases the conditions often remained almost like those of a forest, owing to the large trees employed as shade and the growth of the coffee itself.

The soils are lateritic, varying in colour from red to grey, chocolate, or deep brown, and are weathered from the orthoclase-hornblende-syenite of Mlanje and the older metamorphic rocks, including a variety of crystalline schists and gneisses, of the Shiré Highlands. They are, in general, adequately to richly provided with the essential plant foods, the phosphorus, however, being largely in an unavailable condition. The percentage of iron and aluminium is high and the soil reaction is generally acid. The darker soils are rich in organic matter. On the slopes and ridges the soils are generally very deep and the texture is open, permitting free drainage and aeration. In the hollows ("dambos") which are a characteristic feature of the Nyasaland highlands, the clay subsoil may come near the surface and the soil is stiffer, requiring deep drainage. In these hollows root disease is, so far as I could observe, entirely absent from the tea, but I was informed that they were ordinarily devoid of trees and this, rather than soil conditions, may be the reason for their immunity from root disease.

Round Mlanje the tea flushes in the rainy season from December to April, but plucking becomes impossible when the flush is checked as the cold weather sets in. This immediately follows the rains and precedes the hot season in October to December. That crops exceeding 500 lb. to the acre can be obtained in a four months' season, during which there is also a constant battle with the weeds and grass which grow so fast that they can scarcely be held in check, is a sufficient tribute to the fertility of these soils and the forcing effect of the rainy season. Much of the rain falls in short sharp showers, succeeded by periods of bright hot sunshine, and these conditions induce an intensity in the development of weeds and in the flushing of the tea with which none but exceedingly fertile soils could cope. This fertility is natural, since manuring is by no means general: when the land is first cleared it appears to be high in both the top and the deeper layers of the soil, but after clearing there are indications that the top soil loses fertility through the action

of wash and possibly of other factors as well. In analyses of severely washed, unfertilized Mlanje soils that I have seen, where no attempt was made to separate the surface from the subsoil, the results indicate that the essentials for good tea soils are more fully provided than is common in Ceylon.

In the rest of the Shiré Highlands the rainfall is generally insufficient for tea. The area suitable for tobacco is large but the only other district in which tea is being planted is Cholo, where with a rainfall of only about 60 inches and a colder climate, crops of 400 lb. to the acre are likely to be difficult to obtain. In Mlanje, however, less than half the available land suitable for tea is at present in bearing, and extensions now contemplated should more than double the output. The yield per acre is also being increased in some gardens by fertilizing and improved soil and bush management, while in quality, at present distinctly low, there is also evidence of improvement with the growing of better "jats" (varieties) of bush and more experience in manufacture. Both yield and quality are at present low on the average and one, or preferably both, must be improved if the district is to prosper in the face of rising labour charges. The labour is mainly migratory, and is short from December to February but generally sufficient for the rest of the year. The shortage in the early part of the rains is the chief reason for the frequent failure to keep the weeds down during this period, in which the bushes may become almost hidden from sight in the long grass and other vegetation.

Considering the physical and chemical properties of the soil, the root development of the tea is somewhat disappointing. This is particularly noticeable in young bushes, one to two years after planting out. In such bushes it is common to find no lateral root development in the first eight or ten inches of soil. Small laterals form but fail to provide a root system. Taproot development, however, is vigorous and lateral systems of considerable size early appear in the deeper layers. Subsequently, a surface lateral system arises below the collar of the bush, no doubt as a result of the vigour imparted to the plant by the deeper systems. The mature bush has frequently a substantial growth of stout laterals a few inches below the surface of the soil, the taproot continuing to show strong laterals as it is followed down, but in many cases the young bushes have no hold in the surface soil and if the taproot is broken at a depth of eight or ten inches the bush comes away with a slight pull. Even in mature bushes there is often a lack of surface feeding roots while a tendency for the stout surface laterals to turn down towards the deeper layers has also been noticed.

In endeavouring to account for this type of root development, which must reflect on the vigour and health of the bushes, attention was early attracted to the prevalence of soil erosion and surface wash. It was quite evident that many of the slopes had suffered severely in the past from the loss of the surface soil by rain washing. A rainfall of two inches in an hour is said to be not infrequent in the early part of the rainy season, and a fall of nearly nine inches in 24 hours occurred during my visit. Under such conditions the loss of surface soil must be very severe when the protection of the forest is removed. The loss will vary with the steepness of the slope (rate of flow of the water) and the nature of the soil. The organic matter and fine particles, of most importance to fertility, are the most readily affected by wash and with their loss there is a reduction in the water-holding capacity of the soil. The first heavy rains after the hot season are likely to be the most destructive : later on the growth of weeds, and drainage by the establishment of percolation to the lower layers of the soil may diminish the damage. During the hot dry weather, however, the weeds die down, and the less deep cultivation the soil gets the greater the run-off on the first rains and the resulting loss of fertility in the upper layers. The Nyasaland Agricultural Department called attention to the evils of soil erosion in the strongest terms in Bulletin No. 1 of 1924, in which Captain A. J. Hornby, the Agricultural Chemist to the Department, stated that "tree growth has been destroyed for native gardens down to the banks of streams, and with no precautions we may say that the run-off has risen from 33 per cent. in the forested areas to 69 per cent. of the annual rainfall on such lands. The agricultural capital has been allowed to run to waste and can never be replaced by any system of manuring." These warnings, together with the advent of planters with recent Indian and Ceylon experience, led to a serious effort being made in some tea gardens to combat erosion. In a great many places, however, the damage had already progressed very far, and in some, new areas are still being cleared without any provision for checking wash. In these last cases the top soil constituents of value for the feeding purposes of the tea plant are being removed faster than they are formed and a quite obvious diminution in fertility is taking place. That this, in itself, is capable of influencing the progress of root diseases is indicated by the fact that in certain gardens where no effort has been made to combat disease directly but where wash has not, for one reason or another, been severe and manuring has been practised to some extent, the patches of root rot, though numerous, are mostly

of small extent and slow spread. In these gardens the susceptibility to prevailing root diseases is clearly less than where wash has been severe and soil fertility has been allowed to decline.

Field observations indicate that the types of root disease most commonly found in the Mlanje tea are those which are most easily able to affect bushes with a relatively weak root development. Other root fungi of types which are indifferent to the vigour of their victims (well-known examples of which in other crops are the *Fusarium* wilts) do not appear to occur. The poor development of the bushes on severely washed slopes, as evinced by the absence of spreading growth, the yellow colour of the leaves, and weakness of flushing is accompanied in most cases by outbreaks of disease and is, in my opinion, one of the two main factors which have assisted in causing the unusual prevalence of root diseases in this area. Whether there are other minor factors, working in the same direction as that just discussed in weakening root development, is uncertain. It is possible that the apparent infertility of the upper soil layers may be in part due to the heavy falls of rain forcing the soluble plant foods down to the lower levels. It is also possible that the dry season is sufficiently prolonged to cause drought conditions in these layers, so that the early formed laterals cannot obtain sufficient moisture for their development. Weeds may also play a part by enfeebling the growth of the green parts of the bush and thus diminishing the plant food required for forming a strong root system. Observations carried on for a more prolonged period would be necessary to determine these points.

The second main factor predisposing to root diseases in the Mlanje tea is the wide-spread failure to "stump" the ground when it was first cleared from forest. Only in a few cases were the stumps and main roots of the forest trees removed: in most gardens they were left to decay in the soil, with the same result that has been experienced in all tropical and sub-tropical countries when this precaution has been neglected. As the stumps decay, patches of dying tea are noticed around them, and these may continue to expand for a considerable period unless arrested. I have not seen an adequate explanation of this phenomenon, though the immediate cause of the death of the bushes—the action of certain parasitic fungi which attack the root—is well known. How it is that these fungi require the presence of decaying wood, usually in large masses, to start them into activity is obscure. As in other countries, so in Nyasaland, it has been noticed that certain trees are more apt to start root disease than others. The planters generally were agreed that the two worst trees in this respect were the "Mwanga" (*Afrormosia angolensis*) and the "Muula" (*Parinarium mobola*), the former a very hard wood and the latter moderately soft. As also in India and Ceylon, there is no evidence that the trees most implicated in this trouble are related to one another either botanically or in their physical characters. *Grevillea robusta*, which is found in some numbers as a shade tree in the tea, has not yet reached an age when its well-known tendency to start root diseases would show up: observations in other countries show that the tree is harmless so long as it is growing, and only becomes a menace after it is cut down and the stump left to rot in the ground. *Albizzia moluccana*, another known offender, is occasionally used as shade and will, no doubt, prove as troublesome as it has in Ceylon. The indigenous *A. fastigiata* ("Chikwani") is suspect but has not been proved to cause trouble. Others, such as a local *Ficus*, were mentioned to me as dangerous, while the "Mbawa" or African mahogony (*Khaya senegalensis* var. *nyasica*) belongs to a genus that is known to be susceptible to one of the root rots (*Armillaria mellea*) prevalent in Nyasaland, but whether it can initiate an attack is uncertain. It is obvious that definite information on these points could only be obtained during a longer period of observation than was available to me.

Enquiries led to the conclusion that the root disease patches begin to appear usually about five to seven years after the forest is cleared, and they may persist, if unchecked, for many years. Mwanga stumps were found still fairly sound after 15 years, and there is no reason to doubt that such stumps could initiate delayed outbreaks, just as in India and Ceylon attacks are known to have started from stumps 14 years old.

Of the four fungi hitherto identified as causing root diseases of tea in Nyasaland, two, namely, *Armillaria mellea* and *Ustulina zonata*, are forest fungi. The former is known to be able to attack potatoes, but the disease thus caused is exceedingly rare and, in general, it may be said that annual plants growing in arable soils are free from both species. What may be called forest conditions—shade, undisturbed soil, plentiful supplies of organic matter, high soil moisture, and the like—further their development. So far as I am aware they are generally found in other countries only to a moderate depth in the soil and their presence below two feet appears to be rare. In the loose, well-aerated Mlanje soils, however, they go deeper, at least to two and a half feet. Moisture is essential to their growth and, leaving aside the hollows known as "dambos" already mentioned, they appear to be more prevalent the moister the soil. The low evaporation from, and high moisture

capacity of forest soils are, therefore, particularly favourable to these two fungi. At first sight it might appear that the soil conditions on the washed slopes in which root diseases are most prevalent are not such as would favour these fungi. They undoubtedly persist, however, on the rotting timber in these soils, the absence of drainage and the poor cultivation help their development, and the weak root system in the top soil renders the bushes particularly susceptible to their attack.

The other two, *Botryodiplodia theobromæ* and *Macrophomina phaseoli*, are found in arable and grass as well as forest soils and are known to attack annual plants. The conditions favourable to their development are clearly not the same as with the first two, and there is little evidence that they start from rotting stumps.

Besides the diseases caused by these four fungi another, and in some respects the most serious, of the tea diseases encountered in Mlanje has many of the characters of a root disease though no parasite has been found in the roots of affected bushes. Its occurrence will be more fully discussed below.

Throughout the whole of Mlanje tea district these five diseases occur probably in every garden. Stem and leaf diseases also are found but, except for the stem canker associated with *Macrophoma theæ*, are of little importance. In particular the two serious diseases red rust, caused by *Cephaleuros parasiticus*, and thread blight, caused by several species chiefly of the genera *Corticium* and *Marasmius*, are unknown. The harmless leaf form of red rust (probably due to the allied *C. mycoidea*) is not uncommon, but a careful search failed to disclose any but a few small superficial patches on the stem, usually just below the insertion of the leaves. Of the leaf diseases, the grey and brown blights (*Pestalozzia theæ* and *Glomerella cingulata*) occur, as they do wherever tea is grown, but the damage done by them was negligible during the period of my visit, though I was informed that they had been severe in places in 1926, possibly as a concomitant of the rather severe infestation by mosquito blight (*Helopeltis bergrothi*) in that year. Even in the oldest tea seen (there are a few areas with bushes over 30 years old) the above-ground parts of the plant were remarkably clean and free from blights, possibly as a result of the relatively long dry period in the climate of the district. Of the serious root diseases of tea known in other countries, those due to *Rosellinia* spp., *Fomes lamaœnsis*, and *Poria hypolateritia* were not encountered.

In the tea seedlings still in the seed-beds *Macrophomina phaseoli* was associated with a rot at about the level of the seed, and heat canker was found in a few cases. In young tea (one to two years after planting out) *Botryodiplodia theobromæ* and *Ustulina zonata* caused more deaths than either *Armillaria mellea* or *Macrophomina phaseoli*. The disease of unknown causation may also have been responsible for some of the losses in young tea, but its incidence at this stage was not easy to determine. *Macrophoma theæ* was reported to have been destructive in seed-beds and young tea in 1926, but owing to the vigorous control measures adopted was only prevalent during my visit in a few areas of planted-out tea that had not yet been pruned. Spreading patches of root disease were not observed in young tea. In the mature gardens *Armillaria mellea* and the obscure disease were far more frequent than the others. *Macrophomina phaseoli* was infrequent on full-grown bushes and was only once found on the roots of a dead bush unaccompanied by any other pathogenic fungus, though somewhat more common on single dead roots, in one case accompanied by death of a few branches above.

A more detailed account of these various diseases, the only ones of importance observed, follows.

Root and Collar Crack Caused by Armillaria mellea.

The tea disease caused by *Armillaria mellea* has previously only been reported from Java,[1] where it is found mostly at altitudes of 4,000 ft. or over, *Cinchona* also being attacked, and from Uganda,[2] where it is said to be the commonest cause of root disease in a considerable number of woody plants, amongst which tea is mentioned. The fungus itself, a well-known species in temperate zones, is not common in the eastern tropics; it has not been seen in Ceylon, while in India it has only been recorded at rather high altitudes (over 7,000 ft.) in the Himalayan pine forests. In Africa, however, it is more frequent: in the Gold Coast it is the cause of a serious disease of cacao (*Theobroma cacao*) to which the name "collar crack[3]" has been given, and has also been found attacking the African mahogany (*Khaya* spp.), mango (*Mangifera indica*), avocado pear, *Cola acuminata*, *Chlorophora excelsa*, *Funtumia africana*, coco-nut, the oil palm (*Elaeis*

1 Palm, B., "Over de door schimmels veroorzaakte wortelziekten van de theeplant. III. Beschrijuing van eenige wortelziekten."—Meded. Proefstat. voor Thee, LXI, 1918.

2 Small, W., "The diseases of Coffea arabica in Uganda."—Uganda Dept. of Agric. Circ. 9, p. 20, 1923.

3 Dade, H. A., "Collar crack of cacao (*Armillaria mellea* (Vahl.) Fr.)"—Gold Coast Dept. of Agric. Bull. 5, 1927.

Fig. 3.—Collar of old tea bush killed by *Armillaria mellea*, showing cracking and white mycelial sheets.

Fig. 5.—Root of tea bush killed by *Armillaria mellea*, showing longitudinal bands of xylostroma and (above) white mycelial layer in the bark.

Fig. 4.—Taproot of tea bush killed by *Armillaria mellea*, showing black frills of xylostroma and (below) black lines in the wood.

Fig. 6.—Roots of tea bushes killed by *Armillaria mellea*. Left, root split into two pieces, the inner faces of which are lined with white mycelium. Right, below, black line in wood continued as xylostromatic band on surface; above, continuous white mycelial sheet in the bark.

guineensis), and other trees and herbaceous plants, while in north Africa it causes a root disease of fig trees. In Nyasaland Mr. J. B. Clements, Conservator of Forests, has reported it[1] on the Mlanje cedar (*Widdringtonia whytei*), the successful planting of which on Zomba Mountain has been seriously interfered with on account of its ravages, and I saw mangoes, *Cedrela toona*, and *Poinciana regia* dying from what appeared to be the same disease, while the brown collar rot of coffee observed in the Ncheu district is possibly due to this fungus.

On tea it causes a wet rot affecting the tap root and main laterals, sometimes also extending into the stem well above soil level (fig. 3). The rot is so wet that water can be wrung out of the affected roots, which in late stages of the disease become softened and pulpy. This wet rot is also frequently found in cacao affected with collar crack and has been ascribed to the action of secondary bacterial invasion. The chief symptom on the affected parts is the presence of conspicuous, raised black lines or narrow bands running longitudinally on their surface (figs. 4, 5, 6), and usually representing the external growth of radial sheets of mycelium (xylostroma) which ultimately disrupt the wood in the direction of the medullary rays and lead to radial cracks separating the affected root or stem into elongated, wedge-shaped strips. In the early stages the woody tissues remain firm, but it soon becomes possible to tear the root longitudinally into two or more strips, the inner faces of which are lined by white or dingy mycelial sheets (fig. 6). At a later stage the whole of the wood softens and rots. The cortex is early penetrated by sheets and strands of white mycelium, running chiefly parallel to the surface of the bark and producing a mottled appearance, due to alternations of white mycelium and brown bark, when the latter is shaved away tangentially. On careful dissection the sheets are found to form a more or less continuous layer (figs. 3, 5, 6), which, when growth is active, extends either through the middle of the bark or just external to the cambium for a considerable distance, the growing margins being spread out fan-wise. These symptoms are very similar to those described on cacao in the Gold Coast and they exactly resemble those shown in the photographs of the split-canker of tea in Java caused by *A. mellea*.[2] Rhizomorphs are occasionally found on the surface of the affected roots as black, rounded or flattened strands, closely resembling black roots, a couple of millimeters or more in diameter. They are rare under African conditions and were only found on one tea bush in Nyasaland. This bush, which was nearly dead from a typical attack, also bore clusters of sporophores, medium sized toadstools, in its centre, and other similar clusters were found around the base of a dead *Poinciana regia* tree bordering the tea, in a line in which several deaths had occurred from root disease. Sporophores are evidently formed much less often in tropical Africa than in Europe and they are generally smaller and more deeply coloured and the fungus forms rhizomorphs less regularly than in the temperate forms of *Armillaria mellea* so familiar in woods in England.[3] In Java the form which causes the white root rot of *Cinchona* has been grown in pure cultures[4] in which it produced toadstools in clusters of two or more, yellowish-brown to brown, the stalks 5 to 6 cm. high by 5 to 6 mm. broad and caps 5 to 6 cm. across. No ring is present in the mature specimens of this form, but one can be seen when they are young. The spores are hyaline, ovoid-elliptical or elliptical and slightly pointed, measuring 7 to 9 by 5 to 6 microns, and borne on whitish gills which touch the stem and are somewhat decurrent. Rhizomorphs are not abundant but form readily in culture. Still smaller forms occur in the Java mountains and in the Cameroons and have been recorded as *A. mellea* var. *javanica* and var. *camerunensis*, respectively:[5] the first is described as lurid brown, darker at the top, 2 to 3 cm. in diameter, with a hollow stalk up to 5 cm. high and 2 to 3 mm. thick, a white ring, adnate gills, and hyaline, subglobose spores, 6 to 8 microns in diameter, while the second was only ½ to 1 cm. across. The Nyasaland specimens were too old for accurate description but they would pass for old *A. mellea*, and the presence of rhizomorphs and general characters of the disease leave no doubt as to its causation by this fungus.

The most severe attack of *Armillaria mellea* observed was in a garden planted in 1915 on land cleared from forest containing a considerable number of trees of *Parinarium mobola* and

1 Clements, J. B., "Report of the Chief Forest Officer."—Ann. Rept. Nyasaland Dept. of Agric. 1925, p. 19, 1926.

2 Bernard, C., "Aanvullende mededeelingen over de wortelziekten van de thee."—Meded. Proefstat, voor Thee, LXIa, Pl. III, 1919.

3 Gard has recently described ("Rev. Path. Vég. et Ent. Agric.," XIII, p. 183, 1926) a form of this fungus attacking the walnut in France which seems so have many points in common with the tropical African form. In the United States the fungus known as *Clitocybe tabescens*, which has been regarded by some as only a variety of *A. mellea*, causes a root rot of vines and of fruit and forest trees which closely resembles that here described.

4 Rant, A., "The white root-fungus of Cinchona."—Recueil des Trav. Bot. Neerlandais, XIV, pp. 143-148, 1 pl., 1 fig., 1917.

5 Hennings, P., "Fungi monsunenses."—*Monsunia, I*, p. 20, 1899: *ibid.* "Fungi camerunenses, I."—*Engler's Jahrb.*, XXII, p. 107, 1895.

Afrormosia angolensis. Some ten acres were affected and 75 per cent. of the original bushes had been killed. The field sloped down to a deeply-drained valley at right angles to the forest which bounded it on one side, and was separated by a road on the side opposite the latter from another garden of the same date. A great part of the ridge and slope had bare patches and young supplies, but the bottom of the slope was without a single case of disease and the latter was less severe on the side furthest from the forest, though patches reached the road in several places. That the road had checked extension considerably but not entirely prevented it was evident from the fewness and small size of the patches in the part of the second garden adjoining it. Out of some 20 bushes examined, only three were without symptoms of *Armillaria* attack in the top foot or so of the root system and these possibly were affected lower down. The bushes died gradually and generally from one side, this unilateral type of attack being characteristic of most of those caused by *Armillaria* that were seen. The garden had not been stumped after clearing from the forest, there was no shade, weeds were few, and wash had been unchecked and was doubtless considerable.

A few miles away, in another estate, several gardens of heavily shaded old tea were seen in which there were numerous patches of root disease of the same type, but these patches were small, isolated from one another, and evidently spreading slowly. The soil had been fertilized with cattle manure and a growth of low weeds encouraged with a view to checking wash. In this estate, where the tea bounded the still-standing forest, its edges were scalloped with numerous semi-circular patches of larger size than those in other parts, the appearance strongly suggesting that the attack was extending into the tea from the living forest. I was informed by Mr. Clements that this phenomenon was very apparent in his Mlanje cedar plantations and that he had checked it by trenching. The relatively low percentage of loss in these last-mentioned gardens may be attributed to the vigour of the bushes resulting from fertilizing and the prevention of wash, as stumping had not been done. Where extension was going on, the attack on the bushes was nearly always unilateral, half the bush often being dead while the rest was more or less normal.

Similar small, sharply-defined patches were seen in another estate in gardens cleared from very heavy forest in 1911-12 and stumped after clearing. Some of the old *Afrormosia* stumps were still undecayed. The attack was generally unilateral and every case examined had the typical root cracking. It is evident that neither stumping nor fertilizing will prevent the attack of *Armillaria mellea*, but the small patches in the two last-mentioned estates should be easy to control.

Apart from these spreading patches (various intermediate types of which between the small, sharply defined patches and the larger, irregular ones often intercommunicating, were seen), a number of isolated deaths from the same type of root rot were met with. The attacks killed the bush very rapidly, causing it to wither up completely with its leaves still attached. These single withered bushes with brown or even still green dead leaves are very conspicuous. In one place three of them were found near together and a patch was probably starting, but wherever good sized patches were established, the deaths at the margin of the patch were gradual and preceded by the shedding of the leaves. Even in these gradual deaths it is rare to find new shoots arising from below the diseased branches, though new ones may continue to appear from the sound parts of the bush. In one or two cases, however, a few healthy surface lateral roots from which healthy shoots arose were found in bushes of which the rest of the root system and above-ground parts were dead. In the only instance in which this disease was found in young tea, the bush died in its second year after planting out and its taproot was marked by the characteristic black lines on the surface and mycelial sheets in the bark.

Microscopic examination shows that the mycelium penetrates all the tissues of the affected roots and collar, the hyphæ passing from cell to cell either through the pits in the cell walls, or by boring through the latter. Three types of mycelium are found, a colourless feeding mycelium of slender, branching, hyaline hyphæ; a brown stromatic mycelium confined to narrow layers that appear as black lines when the wood is cut; and a white or yellowish aggregated mycelium forming the sheets in the cortex and in the cracks in the wood, sometimes coming to the surface, where the free edge turns black and produces the thick black bands on the surface of the affected parts. These last are a transitional form to the true rhizomorphs, which are free, thick, leathery, black strands, sometimes flattened and resembling bootlaces, sometimes rounded and like roots spreading through the soil.

The exact manner of infection was not determined, beyond that it was associated in the early stages with the presence of rotting stumps or buried timber in the soil. In temperate countries infection occurs from rhizomorphs which spread through the upper layers of the

soil and infect healthy roots with which they come in contact.[1] In Uganda also spread by rhizomorphs is stated to have been observed,[2] tea bushes having become infected by rhizomorphs which had passed over from a diseased ceara rubber tree (*Manihot glaziovii*). In the Gold Coast spread occurs along the roots, and infection is due to direct root contact. In Nyasaland it is probable that, even though rhizomorphs are rare, spread occurs through the soil, the frequently even centrifugal spread being difficult to explain in any other manner, since the larger tea roots are not often in contact.

Infected roots always show the white sheets of mycelium in and under the bark, and the formation of these appears to take place at an early stage. Underneath them the wood is permeated by hyphæ. Under conditions that are not understood these hyphæ tend in certain places to form swollen bladder-like cells completely filling the cell cavities of the host. This formation starts in the medullary rays and it is possible to find stages in which it is confined to them. More usually, however, it occurs in a continuous layer, reaching from near the surface of the wood to a variable depth towards the centre, and involving all the cell elements, tracheids, fibres, and wood parenchyma. When the band, as is frequently the case, extends along the natural grain of the wood of the root, splitting occurs owing to the destruction of the cell walls, of which frequently nothing but the spiral or scalariform thickenings are left. The cracks thus formed are usually but by no means invariably radial, tangential cracks being not uncommon (fig. 6). When the band crosses the natural grain it does not lead to splitting. The stages of the development of this bladder-like mycelium are accurately described by Hartig,[3] but it was not accompanied, in the trees observed by him, by cracking of the wood. The latter phenomenon, indeed, appears to be rare in the forms of attack seen in temperate countries.

The bladder-like mycelium is at first colourless and thin walled, but soon turns light brown and the walls thicken. In advanced stages the band, seen in section as a narrow black line, consists of a dense mass of angular, often rather small, cells, of a deep brown colour, completely occluding the cavities of the invaded host cells. When cracking occurs or the cell destruction gives room for further development, an extension of fungal growth takes place in the form of masses of elongated, closely appressed cells, which develop into sheets filling the space. Even before any crack is visible these sheets may be found on microscopical examination starting from the stromatic layers of bladder cells. The sheets are much less highly coloured than the bladder-mycelium and may even be almost white, and they are fringed by a silky outgrowth of very fine hyphæ, the lumen of which is almost or quite occluded. At the surface they turn black and thicken up into almost cylindrical masses or protrude from the crack in the form of a black frill. A similar formation can occur in the cortex, typical black bands being sometimes found arising from the white sheets in the bark when the wood below shows no sign of splitting or even of the black lines that precede the formation of a crack (fig. 6, top of root on the right).

In the accounts of black-line formation by this fungus that have previously been given[4] it is stated that the lines move gradually forward as the rot progresses into the tissues, marking the limit between two different stages of the decay of the latter. As new host cells are filled with the bladder-mycelium in the direction in which the rot is advancing, those behind become emptied by the bleaching and dissolution of the fungal cells. While it is true that the line divides the wood into areas that differ in appearance and in the extent of the decay that has been caused, no evidence was seen that its position progressively shifts forward. It appears to be laid down in the position that it continues to occupy definitively and the subsequent changes that occur in the same position often lead to the formation of a crack. The whole process is much more like the development of some defensive reaction on the part of the host or the parasite.

The measures to be adopted for the control of this disease will be given after that next to be described, as they are generally similar in the two cases.

1 Day, W. R., "Parasitism of *Armillaria mellea* in relation to conifers."—Quart. Jour. of Forestry, XXI, pp. 9-21, 1927.

2 Small, W., *loc. cit.*

3 Hartig, R., "Die Zersetzungserscheinungen des Holzes," pp. 59-62, Pl. XI, figs. 1-5, 1878.

4 Hartig, R., *loc. cit.* Hiley, W. E., "The fungal diseases of the common larch"—Oxford, Clarendon Press, 1919, pp. 155-158.

Stump Rot caused by Ustulina zonata.

Of the several forms of stump rot, that is to say diseases arising from rotting stumps in the soil, that caused by *Ustulina zonata* is the commonest on tea in Ceylon and probably also in India.[1] The parasite is widespread throughout the tropics, attacking a number of woody plants, the most important of which is Pará rubber *(Hevea brasiliensis)*. It frequently infects coffee, tea, rubber, and the like on old forest land in Kenya, where even temperate fruit trees, such as the peach and pear, have been killed by it. It is also known to occur in Uganda and the Gold Coast but does not seem to have caused serious losses in either case. In Java, where it is known as the root-collar disease,[2] a few serious outbreaks have been recorded, but as a general rule *Ustulina zonata* is not regarded as a serious trouble in tea in that country. The fullest studies of its parasitic action have been made on rubber,[3] and in this host conclusive proof of its parasitism has been obtained by inoculation experiments.

No certain cases of root disease of mature tea associated with the presence of this fungus alone were observed in Mlanje. Only in diseased young bushes was *Ustulina zonata* found alone, though it must be presumed from experience elsewere that it is capable by itself of killing the mature bushes. I also failed to find its fructifications on tea, though these are usually fairly frequent where the disease due to it is present, and the diagnosis is, therefore, open to some doubt. Ripe fructifications were, however, obtained from just above ground level on the trunk of a *Poinciana regia* tree bordering the tea and suffering from the root disease typical of this fungus, which had resulted in a weakening of the root system and led to the tree being blown down by the wind. They were also collected in a similar situation on an unknown forest tree that had been removed from the tea in another estate.

In a typical attack of *Ustulina zonata* the tea dies out in spreading patches, which in Ceylon usually start from the stumps of *Grevillea robusta* or *Albizzia moluccana*. The parasite spreads chiefly below ground, though cases have been reported of aerial infection through its spores reaching wounded surfaces, such as pruning cuts, in India and Ceylon, and similar wound infections are not uncommon on rubber in Malaya. In the soil, spread is only possible when an infected root touches or lies very near a healthy one, the mycelium, unlike that of *Armillaria mellea*, extending only along the roots and not through the soil. In some cases in Ceylon a line of dead bushes has been found to follow the course of a main lateral root of *Grevillea* or *Albizzia*. The bushes may be killed rather gradually, losing their leaves little by little, or quite suddenly with most of the leaves attached and either brown or still greenish. In spreading patches the attack is often unilateral, part of the bush dying while the rest appears almost normal. As in the case of bushes attacked by *Armillaria*, it is rare to find suckers or new shoots arising from below the killed branches.

The affected roots bear no external mycelium except black lumps or crusts, in this resembling *Armillaria* where, however, the external crusts are arranged in narrow longitudinal bands. In the bark, too, the symptoms of the two diseases are somewhat similar, except that the sheets are smaller, more fan-shaped, and creamy-white in *Ustulina* instead of being in large uniform layers and often pure white, as in *Armillaria*. There is no tendency to cracking of the wood, but the latter is marked with sharp, angular or wavy black lines, very similar to those caused by *A. mellea* both in appearance and in the manner of their formation.

The absence of longitudinal black bands or frills on the surface of the bark and of radial cracking of the affected wood enables this disease to be readily distinguished from that due to *Armillaria*. It was never found by itself in Nyasaland causing spreading patches of disease, and in every case seen where single mature bushes died without shedding their leaves, *A. mellea* was present and seemed to be the cause of death. It is, therefore, uncertain whether *U. zonata* is a primary cause of disease of mature tea in Nyasaland, though the knowledge of its presence in young tea and in the forest makes this highly probable.

In young one- to two-year-old tea *Ustulina zonata* was sporadic and usually associated with *Botryodiplodia theobromae*, an association which was not found in older bushes. Occasionally it seemed to occur alone, the attack then being near the soil level. These isolated attacks in young

[1] Petch, T., "Diseases of the tea bush."—Macmillan, 1923, pp. 141-146. Tunstall, A. C., "Tea roots, II."—Indian Tea Assoc. Sci. Dept. Publ. 44, pp. 11-12, 1918. Butler, E. J., "Fungi and disease in plants."—Calcutta: Thacker, Spink and Co., 1918, pp. 438-440.

[2] Bernard, C., and Steinmann, A., "De wortelkraagziekte."—*De Thee*, V, pp. 21-23, 1924.

[3] Sharples, A., "Ustulina zonata—a fungus affecting Hevea brasiliensis."—F. M. S. Dept. of Agric. Bull. 25, 1916.

tea near the surface of the soil can scarcely have been due to spread from previously diseased roots but had much more the appearance of wound infection from spores, probably associated with injuries during cultivation.

The fungus at first penetrates the bark and reaches the junction of the bark and wood where it spreads out to form delicate creamy-white fans. It then penetrates through the medullary rays into the wood, where the same two types of mycelium are found as in *Armillaria*. The bladder cells forming the black lines do not, however, cause any splitting of the wood and do not grow out to form sheets or black xylostroma. The only part that reaches the surface of the root is ordinarily the fructifications, which arise on the collar and larger diseased roots when these are above soil level. The mycelium in these situations spreads out on the surface in small yellowish-white plates, lying close to the bark but only attached at one point. Frequently several plates unite by their margins to form fairly extensive, corrugated sheets, several inches across. The single fructification is zoned, and when mature is finely punctate with black dots which mark the mouths of the spore receptacles. Before this stage, however, when the surface of the plate is still whitish and soft, very small spores (conidia) develop in a continuous layer, covering the plate, and as these have been shown to be able to give rise to cultures of the fungus they must play a part in disseminating the disease. The perfect stage arises later, when the crust is dark brown or blackish-purple and brittle, in the form of a layer of flask-shaped spore receptacles (perithecia) buried just below the surface of the crust, only their mouths projecting to form the little black dots referred to above. In these receptacles a second spore form is developed consisting of large, opaque black or dark brown, boat-shaped ascospores, arranged in groups of eight in thin cells or asci. This is the only stage observed in Nyasaland and it is probable that most of the cases of this disease observed in the young tea came from infection by means of these ascospores, which were abundant in the specimens collected on forest and shade trees. Further investigations may show that the typical spreading patches so commonly caused by this fungus in Ceylon around *Grevillea* stumps also occur in Mlanje and, therefore, the control measures described below are designed to meet this possibility.

Control Measures against Armillaria and Ustulina.

Both the root diseases caused by *Armillaria mellea* and *Ustulina zonata* are amenable to a considerable measure of control on somewhat similar lines, especially if steps to prevent their appearance in new clearings are adopted. For this purpose it is scarcely necessary, in the restricted Mlanje area, to attempt to distinguish one from another. The main points to be borne in mind are that both are favoured in their earlier stages by the presence of rotting wood in large masses in the soil and that their spread is chiefly underground.

It is not safe to clear forest land for tea planting in the Mlanje area without stumping. The two fungi are present throughout the district and no estate is free from them. Both seem to be equally capable of starting from rotting tree stumps in the soil, for in no other way can the isolated spreading patches of disease round such stumps be explained. *Armillaria* is evidently also able to extend from the still standing forest into adjoining tea, and *Ustulina* is liable to infect pruning cuts and other wounds by spores, though this is not common except, perhaps, in young tea. The value of stumping is recognized in the district, and not only is most of the newly cleared land being stumped but buried stumps are being dug out in some gardens from the planted-out tea. It is obviously better to remove them before the tea is planted, and this is the first and most essential measure in attempting to secure freedom from root disease. Fortunately, most of the forest consists of small trees and it is only in certain places that large *Khaya* and other trees are found. Some of these might, perhaps, better be dealt with by isolating them by a trench than by digging them out, the large surface laterals being cut through and removed.

In spite of these precautions root disease may appear and a careful watch must be kept to detect any attacks in an early stage. As soon as a bush dies it should be removed and adjoining bushes examined to see if they show signs of attack. Very often several bushes near together are affected almost simultaneously. When this occurs or when a definite patch has appeared, trenching to prevent the underground spread of the fungi should be at once resorted to. No other method can replace trenching as a control measure in small patches. The trench should be three feet deep and should surround the patch and one row of apparently healthy bushes, for it is obvious that the latter may be so recently infected as to show no symptoms above ground, and failure to isolate them will make the trenching useless. The soil from the trench should be thrown into the patch, not outside. Then the dead bushes should be removed, the apparently healthy ones examined on the side towards the patch and also removed if signs of infection are seen, and the

whole patch dug over to a depth of at least two and a-half feet, all fragments of roots being removed as far as possible. The bushes and pieces of root should be piled and burnt in the patch, or, if too damp to burn, should be scorched with straw or dried prunings and left until dry enough to burn. If the removal of diseased bushes is done after plucking has finished, say, in April, a second digging over should be done about October. If the work is carefully done it may be safe to supply in the following rains, say in January or February, using large, strongly-rooted seedlings for the purpose. If experience shows that such supplies are liable to contract infection it will be necessary to postpone supplying until the following rains. Supplying earlier than nine or ten months after removing infected roots is unsafe, and tests may show that even this period is insufficient to rid the soil of infection. When a single bush dies, trenching is unnecessary if the soil be well dug over after the bush is removed, and the roots of bushes in contact with it are examined. In this case a great deal will depend on whether the bush can be removed immediately it shows clear signs of root disease. If labour requirements force it to be left for some months, neighbouring bushes are likely to be infected and must also be removed. In all cases an attempt should be made to discover whether the attack has come from a rotting tree stump, and this should be removed when located.

When the disease has progressed unchecked for a number of years the patches become so irregular and extensive that trenching may be impracticable. More than one affected garden was seen in which it would be almost impossible to devise any system of trenches that would effectively preserve the still healthy bushes. In such cases reliance must be placed on the removal of affected bushes and thorough digging of the soil so as to leave as few roots in it as possible.

Liming the soil after removing the bushes is usually recommended, its main object being to promote the rapid decomposition of fragments of roots in which the fungus may be living. Where lime is cheap and easily available, so that heavy doses can be given, it is worth using, but it cannot replace thorough cultivation, whereas the latter can replace liming. There is little doubt that the more thorough and deeper the cultivation the less favourable the soil becomes for the two fungi under consideration, and the thorough turning over of the soil two or three times after removing infected roots should be effective in freeing it from them.

When the tea abuts on the forest a deep trench should be dug separating one from the other, in order to prevent continual reinfection from the latter by *Armillaria mellea*. A watch should also be kept on shade and avenue trees, and all cases of death from root disease treated in the same way as in the tea itself. It is exceedingly unwise to pile the stumps of uprooted or fallen trees in the neighbourhood of the tea as is sometimes done, owing to the tendency for ripe fructifications of *Ustulina zonata* to develop on them. If they cannot be removed they should be scorched, since fructifications were not found on the stems of scorched trees.

The above are the chief direct methods of fighting the root diseases caused by these two fungi. They are based on the fact that buried stumps and diseased tea roots are the common sources of infection. Land that is habitually kept free from decaying wood, such as ordinary plough land, does not usually contain these fungi. Trenching would be unnecessary could all diseased roots and other decaying wood be removed to a depth of say three feet, and it is being discouraged in Assam in favour of the latter procedure. But it is not always convenient to provide the necessary labour for thorough digging over when the first cases are seen, and the isolation of the patch by trenching after removing the larger roots may prevent undue spread until the ground can be thoroughly dug over. Indirect methods of prevention calculated to improve the vigour of the bushes so as to enable them to resist attack will be dealt with later, as they are applicable to all the types of root disease encountered.

Internal Root Disease caused by Botryodiplodia theobromæ.

The fungus for which the name *Botryodiplodia theobromæ* is still used, though it is extremely doubtful whether it is the correct one, is a common species in the tropics, where it is found in forest and grass land as well as in arable soils. Its parasitism has been proved in the case of certain host plants, such as cacao, sugar-cane,[1] and *Hevea* rubber[2] and there is little doubt that it can also attack tea, on which the disease attributed to it is known as internal root disease in

1 Howard, A., "On Diplodia cacaoicola P. Henn., a parasitic fungus on sugar-cane and cacao."—*Ann. of Bot., XV.* pp. 683-701, 1901.

2 Bancroft, K., "The die-back fungus of Para rubber and of cacao (*Thyridaria tarda*, n. sp.)."—F.M.S. Dept. of Agric. Bull. 9, 1911.

Ceylon and India. In many cases, however, it is found on roots and stems after they have been injured by some other agency, and its presence on dead tea roots is by no means evidence that it caused their death. In Africa it is responsible for a die back and pod disease of cacao in the Gold Coast[1] and Uganda[2] and it is associated with a root disease of apple trees in Kenya[3].

In India young tea is said to be most frequently attacked on cleared grassland and in coarse sandy soils, but elsewhere it has not been possible to associate the disease with any particular type of land. It is commonest in old tea in the low country of Ceylon, but has also been observed on young bushes and at higher altitudes. The attack usually develops only after pruning and it may increase progressively from the first cutting back given after planting out through several successive prunings until as many as 50 per cent. of the bushes are affected. Though it is not so common as the diseases caused by *Ustulina* and some other tea root parasites, it is said to be capable of killing a greater number of bushes in each individual outbreak than any other root disease.

The attack becomes visible six weeks to three months after pruning, the pruned bush sometimes failing to put out any new shoots and being rapidly killed. When new shoots grow, they may remain healthy until they are six or eight inches long and then die back. In other cases single branches may die or the bush may remain moribund for a long time. In the early stages the leaves of affected bushes or parts of bushes become mottled with pale yellow or yellowish-green patches. Then they turn black at the tips and along the edges and fall prematurely. The roots appear to be clean and healthy until they are cut, when the wood is found stained pale bluish-black. The colour is due to an internal mycelium of stout, smoky-black hyphæ which give off finer hyaline branches. There is no external mycelium and no visible accumulation of hyphæ into sheets and strands between the layers of the bark. On examining the roots with a lens, especially after death, slightly prominent, round, black bodies of small size, which are the fructifications of the fungus, may be detected almost buried in the bark. Frequently, however, they are not visible until the surface of the bark is shaved away, when they appear as small black circles with a white centre. Various other fungi found on dead tea roots in Nyasaland have a somewhat similar appearance, so that it is safer to rely on the characteristic bluish-black or slate-coloured staining of the wood for a diagnosis. The fructifications are spherical spore receptacles (pycnidia), sometimes united into clusters in a stromatic mass of black mycelium, and they contain large, oval spores which, when ripe, are uniseptate and dark brown, though they are white in the mass and unseptate when young. In the early stages the mycelium may be found only in the finer roots, but direct attack on the tap root also occurs. Later on the dark mycelium may rapidly penetrate all parts of the root system as well as the base of the stem.

A further, perfect, spore-form of this fungus has been described under the name *Thyridaria tarda*,[4] but is not generally accepted. More recently[5] it has been suggested that the perfect stage is *Physalospora rhodina*, but this has not yet been found associated with the tropical forms of the fungus.

The patches caused by this disease may be very large, and in Ceylon may develop around the stumps of *Albizzia moluccana* trees that have been ringed or cut down when they have grown too large.[6] The fungus develops on such stumps and produces spores in abundance, which infect the surrounding tea. The same tree grown as coffee shade has also proved liable to attack in Uganda.[7] Infection by spores often takes place through wounds in the larger roots caused by cultivation and also in stems as a result of pruning. Observations indicate that they usually do not succeed unless the wood has been dried out after pruning. A more frequent source of internal root disease is probably the accumulation of buried prunings in the soil, as the fungus grows and sporulates freely on such prunings and patches have been observed to start around the holes in which they had been buried.

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1 Bunting, R. H., and Dade, H. A., "Gold Coast plant diseases," p. 49.—London : Waterlow and Sons (1924). Dade, H. A., "Economic significance of cacao pod diseases and factors determining their incidence and control."—Gold Coast Dept. of Agric. Bull. 6, 1927.

2 Snowden, J. D., "Report of the Government Botanist for 1920."—Ann. Rept. Uganda Dept. of Agric. for 1920, pp. 43-46, 1921. Small, W. "Annual Report of the Government Mycologist, *ibid.* for 1924, pp. 18-20, 1925.

3 McDonald, J., "Annual Report of the Mycologist."—Ann. Rept. Kenya Dept. of Agric. for 1924, pp. 106-111, 1925.

4 Bancroft, K., *loc. cit.*

5 Stevens, N. E., "Two species of Physalospora on citrus and other hosts."—*Mycologia*, XVIII, pp. 206-217, 1926.

6 Petch, T., *loc. cit.*, p. 152.

7 Small, W., "Annual Report of the Government Mycologist for 1921."—Ann. Rept. Uganda Dept. of Agric. for 1921, pp. 52-53, 1922.

Cases of the root disease caused by this fungus were not common in Nyasaland, except in young tea, during the period of my visit. Mature dead bushes were never found to have more than an occasional root infected, and no patches of dying bushes suffering from internal root disease were seen. The only instances in which bushes appeared to have been killed by *Botryodiplodia theobromæ* were in the first or second year after planting out, and such attacks were always sporadic. They were sometimes associated with the presence of *Ustulina*, so that it was impossible to decide which was the primary cause of death. I was informed, however, by Captain Smee, the Entomologist to the Nyasaland Department of Agriculture, that during the dry period of the year the fungus is present on the roots of many dead bushes, and it is clear that much further investigation is required before its relative importance as a cause of tea root disease in Nyasaland can be determined.

This fungus is a weak parasite, especially in the underground parts of plants, and is one of those that can best be fought by improving the general health of the bushes. There is no evidence that it is able to infect tea by the growth of mycelium from buried stumps, so that stumping has no influence on its attacks, except in so far as the wood of decaying stems and roots of such trees as *Albizzia* may serve as a reservoir from which spores are discharged into the surrounding tea. It has been noticed in India that there are few spores discharged in the earlier weeks after the cessation of the rains, and it is recommended that when heavy pruning is required in tea on areas where the disease is prevalent, it should be done during this period, and at the same time two or three ounces of nitrate of potash should be applied around each bush in order to stimulate the new growth. In such land, also, prunings should never be buried but should be collected into heaps and burnt. There is some indication in the Mlanje district that young tea is more liable to be attacked when planted on cleared grass land, as in northern India, and in such areas at least the prunings should be burnt, not buried.

THE SCLEROTIAL ROOT DISEASE CAUSED BY MACROPHOMINA PHASEOLI (RHIZOCTONIA BATATICOLA).

This fungus has only been recorded on tea in Ceylon, where it was first reported in August, 1926,[1] though the question of its parasitism on this host was left open pending further study. Previously it has been investigated in some detail as a parasite of various plants in India, the United States, Egypt, and Uganda, and in 1927 there arose a considerable controversy as to its importance as a cause of root disease of woody plants in Ceylon. In India[2] it attacks cotton, jute, groundnuts and cowpea and has been found on many other plants: in the United States,[3] sweet potatoes, ordinary potatoes, and beans; in Egypt,[4] cotton, cowpeas, and beans; and in Uganda,[5] some forty different plants, including coffee (on which it is reported to cause a serious root disease), cacao, eucalyptus, and a number of woody plants used as shade or green manure in tea and coffee plantations. In Kenya also it is one of the causes of coffee root disease.[6] In Ceylon the number of its hosts appears to be at least as large as in Uganda (including a high proportion of the economically valuable plants of the Colony)[7] and it is evidently one of the most nearly omnivorous parasites known. It appears to be confined to warm countries, its distribution corresponding roughly to the areas in which cotton can be grown.

In Nyasaland *Rhizoctonia bataticola* is associated with a disease of tea seedlings still in the nurseries, and it was also found sporadically on the roots of dead bushes about a year after planting out and, less often, on those of mature bushes.

The seedling disease was severe in only a few beds in one nursery, though a number of individual attacks occurred in several other nurseries involving both newly imported and acclimatized seed. The leaves of affected seedlings turn pale and then wither and fall off more or less completely. The shoot dies back to the collar, but usually new shoots arise at or below the surface

1 Small, W., "Sclerotium bataticola Taub."—*Tropical Agriculturist*, LXVII, pp. 94-5, 1926.

2 Shaw, F. J. F., "The morphology and parasitism of Rhizoctonia."—Mem. Dept. of Agric. India Bot. Ser., IV, 6, 1912. Shaw, F. J. F. and Ajrekar, S. L., "The genus Rhizoctonia in India." *ibid*. VII, 4, 1915.

3 Taubenhaus, J. J., "The black rots of the sweet potato."—*Phytopath.*, III, pp. 161-164, 1913.

4 Briton-Jones, H. R., "Mycological work in Egypt during the period 1920-1922."—Min. of Agric. Egypt, Tech. and Sci. Service Bull. 49, 1925.

5 Small, W., "A Rhizoctonia causing root disease in Uganda."—Trans. Brit. Mycol. Soc., IX, pp. 152-166, 1924. *Ibid*. "On the identity of Rhizoctonia lamellifera and Sclerotium bataticola," *ibid*. X, pp. 287-302, 1926. *Ibid*. "Notes on species of Fusarium and Sclerotium in Uganda."—Kew Bull., 1925, pp. 118-126, 1925.

6 McDonald, J., "Fungoid diseases of coffee in Kenya Colony."—Kenya Dept. of Agric. Bull. 3, 1926.

7 Small, W., "Further notes on Rhizoctonia bataticola (Taub.) Butler."—*Tropical Agriculturist*, LXVIII, pp. 73-75, 1927; LXIX, pp. 9-12, 1927.

of the ground and the plants often recover. On pulling up plants after the leaves have withered, a wet patch of partially rotted bark is found extending along the taproot and base of the stem for about half an inch at the seed level (one to two inches below the surface of the soil). This rot usually involves the seed (which may be reduced to a slimy mass probably by the action of secondary organisms), but it does not ordinarily penetrate into the woody tissues of the seedling, and in those that recover little signs of its presence are found. The lateral roots are clean and apparently quite free from this fungus. The surface of the rotting bark in all cases examined bore moderately stout, brown hyphæ of the type characteristic of *Rhizoctonia*, and the small black sclerotia that distinguish *Rhizoctonia bataticola* were found in a few roots when the bark was peeled off, though they are by no means universally present. In cotton seedlings also it is not easy to find sclerotia, and the cause of the cotton seedling disease due to this fungus, which is common in India, is often difficult to determine without cultural work. The most severely affected seed-beds were in the lowest part of a nursery, these particular beds being bounded on two sides by tall grass which kept the air moist and stagnant.

Typical sclerotia of *Rhizoctonia bataticola* were found on the taproot of two bushes which had died about a year after planting out, and from one of these a pure culture of the fungus was obtained. A very large proportion of the young tea had died in the field from which these were obtained, a field which had been recently cleared from the same belt of forest as that which gave rise to the most severe attack of *Armillaria mellea* mentioned above. In none of the other cases examined, however, could the cause of death be determined, and it is possible that the field was affected by the disease next to be described.

The only case seen in which a mature bush had apparently been killed by *Rhizoctonia bataticola* was a single dead bush surrounded by healthy tea. It had dried up completely and the tissues, especially those of the roots, were bleached, hardened, and unusually light. The collar showed no signs of fungous attack, but a considerable number of the lateral roots, from one-eighth to half an inch thick, contained numerous hyphæ and characteristic sclerotia in the inner bark and outer layers of the wood. No other parasite was found, and the death of the bush may be attributed with considerable probability to *Rhizoctonia bataticola*. In another case a bush was seen with a dead branch at one side arising from near the ground level and sclerotia of the fungus were found on two roots just below this point. On various other occasions roots of diseased bushes were found with a growth of *Rhizoctonia bataticola* usually in the neighbourhood of wounds inflicted during cultivation or otherwise, but other tea root parasites were present and may have been responsible for the diseased condition.

Tea roots affected by this fungus show little external symptoms; indeed, as a rule, none that can be detected without the use of a good lens, except the condition described above as found on the taproot of diseased seedlings. In older plants the cortex of affected roots is brittle and its inner layers may show a tendency to shredding, coming away from the wood as a bundle of fibres rather than as a single continuous sheet. In the inner layers or, more often, on the surface of the wood very small, rounded or elongated, black dots can often be seen with the lens. Microscopic examination shows that these are composed of thick-walled, brown cells forming small stromatic bodies or sclerotia. The mycelium is generally scanty and is composed of hyaline hyphæ, very variable in diameter and with the branching characteristic of *Rhizoctonia*. The older hyphæ may turn brown and at the same time show a tendency to form clusters of the dark-walled cells. The sclerotia usually appear as the tissues dry up, and the manner of their formation has been fully described by Shaw and Small. They are amongst the smallest known, averaging not much more than 100 microns in diameter.

Under certain conditions, which appear to be difficult to reproduce artificially, this fungus gives rise to a sporing form which was originally described on bean stems from Tunis under the name *Macrophoma phaseoli*.[1] This form has since been obtained on several of the hosts of the sclerotial form from Formosa, the Philippines, India, Uganda, Ceylon, and the West Indies and the most recent study,[2] in which full literature references and synonymy are given, indicates, that the correct name for the organism is *Macrophomina phaseoli* (Maubl.) Ashby. On one of the young tea bushes that had died some time after planting out, a pycnidial form agreeing fairly well with *M. phaseoli* developed near soil level in material brought to England, so that it is probable that the sporing stage of the fungus also occurs on tea. This stage on other plants

1 Maublanc, A., "Espèces nouvelles de champignons inférieurs."—Bull. Soc. Myc. de France, XXI, p. 90, 1905.

2 Ashby, S. F., "Macrophomina phaseoli (Maubl.) comb. nov. The pycnidial stage of Rhizoctonia bataticola (Taub.) Butl."—Trans. Brit. Mycol. Soc. XII, pp. 141-147, 1927.

consists of small black spore cases (pycnidia), smaller and more superficial than those of *Botryodiplodia* and containing a number of colourless, unseptate, elongated spores, measuring about 16 to 30 by 6 to 9 microns in diameter. On tea, however, the spores were only 16 to 22 by 4.5 to 6 microns, which is unusually small for *M. phaseoli*, so that it is not certain that they belonged to the *Rhizoctonia* parasite or that they play any part in the dissemination of the disease.

The accounts of the mycelial characters of this fungus are so discrepant that it is difficult to believe that they all relate to the same fungus. On woody plants in Uganda it is described as forming black crusts and plates on and in the bark, and wavy black lines in the wood and bark of affected roots. Unfortunately, in both East Africa and Ceylon most of the plants on which *M. phaseoli* has been found, including tea, are liable to infection by various other fungi, which often coexist with the sclerotial fungus. So common, indeed, is this association that Dr. Small holds the *Rhizoctonia* to be the primary parasite in all these root diseases of woody plants, the others being secondary followers that at most hasten the destruction of the roots. That the mycelium of some of these has been at times confused with the growth of *M. phaseoli* is clear from the mention both by Shaw and Small of clamp-connections in the hyphæ, pycnidial fungi being devoid of such organs, and it is possible that the crusts and black lines are equally due to mixed infection. Black lines are common in tea roots in Nyasaland on which sclerotia are found, but the latter are so frequently present without any trace of black-line formation that I doubt the connection between the two. In an attempt to distinguish between the black lines formed by *Armillaria mellea* and *Ustulina zonata*, specimens of the former on beech wood from Scotland (where the latter is unknown) and of the latter on rubber from Malaya (where *Armillaria* has not been reported) were compared and were found to be identical. This indicates the impossibility of determining from the characters of the lines in the wood the organism by which they were formed, and it must, for the present, be regarded as doubtful whether *Rhizoctonia* is capable of causing black lines in tea roots.

Besides the typical minute sclerotia, pure cultures isolated from which agreed with those of *M. phaseoli* from various sources grown at the Imperial Bureau of Mycology, other more irregular, often more prominent and shiny, and usually somewhat larger sclerotioid bodies were not uncommonly found on the dead roots and collars of bushes of all ages. Some of these appeared to be associated with pycnidial fungi other than *Macrophomina*. As cultures from these small stromata were not obtained, it was not possible to determine their identity.

Fungi of the genus *Rhizoctonia* are well-known as amongst the causes of damping-off in seed-beds, and the tea seedling disease above mentioned may be included in this category. They are favoured by overcrowding, insufficient ventilation, and excessive moisture. The tea seedling disease associated with *Rhizoctonia bataticola* is, so far as my observations went, usually not severe enough to justify special measures for its control. Where it is found attacking a considerable number of the seedlings, watering should be reduced and if the bed is shaded the coverings should be raised so as to allow the air free access to the beds. It might be advisable to remove them completely at night. The beds should not be sited in localities where there is not a reasonably free circulation of air, and tall grass or the like should be cut down in their immediate vicinity.

Seedlings that have died back in the manner described should not be used for planting out, even when they subsequently put out new shoots, as it is highly probable that the presence of the fungus on older plants is in part due to mycelium and sclerotia transferred with the plants from the seed-bed.

Attacks on older bushes cannot be prevented by any practicable measures, but they appear to be so sporadic as to be of little importance. It is a safe rule to remove all dead bushes when noticed in order to prevent the accumulation of root fungi in the tissues and their subsequent dissemination into the soil.

One other *Rhizoctonia* infection of considerable interest was found on a seedling that had died a year or two after planting out. The roots were covered with a violet growth in long twining strands or thin sheets. This was the mycelium of a fungus agreeing in all essentials with the well-known *Rhizoctonia crocorum*, the cause of the violet root rot of many plants in temperate countries and occasionally in the tropics. However, as *R. crocorum* has recently been shown to be the sterile stage of *Helicobasidium purpureum*, whereas an allied but distinct species, *H. longisporum*, is known on the roots of cacao and rubber in Uganda, it is possible that this *Rhizoctonia* belongs to the latter fungus. There was little doubt that the bush had been killed by its attack, but only one case of the kind was seen and the disease appears to be of no importance at present.

Fig. 7.—An obscure tea disease. Bush attacked from one side.

Fig. 9.—Tea canker associated with *Macrophoma theæ*.

Fig. 8.—An obscure tea disease. Bush in late stage of attack.

Fig. 10.—Tea canker associated with *Macrophoma theæ*. Late stage.

An Obscure Tea Disease.

Reports received indicated that the most serious root disease of tea in Nyasaland was that attributed to *Botryodiplodia theobromæ*, and it was soon evident that a large proportion of the patches of unhealthy or dead tea in the estates visited had many of the characteristics of internal root disease.

These patches were very irregular in shape, and whether they started from a single or several foci of infection, they nearly always showed several areas near together in which all or most of the bushes had died, while between these many of the bushes were healthly. The bare areas were connected with one another by alleys or lines of bushes which were dead or unhealthy, and beyond the limits of the patches single cases, apparently representing advance infections which often missed the nearer bushes to attack those further away, were found. The attack may commence in any part of a garden, except in the clay hollows ("dambos") previously mentioned, and though, in time, a great part of the garden may appear sickly, the advance is always roughly centrifugal and the parts furthest from the original attack are the last to become affected.

This disease appears to be responsible for more injury than all those previously mentioned taken together. It was the only disease causing spreading patches seen in the Cholo area and was the cause of exceedingly grave losses in some Mlanje estates. When of several years' standing, the total number of bushes affected in each attack ran into hundreds, and supplying with healthy seedlings had not checked the losses since the new plants were often attacked in their turn.

The above-ground symptoms are somewhat similar to those described in the internal root rot of tea first seen by me in Assam in 1902 and of which a short account was published in Watt and Mann's "Pests and Blights of the Tea Plant," 2nd Ed., pp. 414-416, 1903. The first sign is the development of shoots bearing small, narrow, pale green leaves, often with their edges upturned. The pale colour is due to a slight yellowing of the intervenous parts of the leaf blade, the veins remaining a darker green colour so that they show up prominently, just as in the Assam disease. As these shoots are not plucked, the bush soon assumes a twiggy appearance. In spreading patches these symptoms may develop on one side only (fig. 7), usually that from which the patch is advancing, but the side attacked does not die quickly as in unilateral infection by *Armillaria mellea* or *Ustulina zonata*, being marked, during the first rainy season at least, only by the pale narrow leaves and thin twiggy growth of the affected parts. In the following dry season these twigs may die back, but in the next rains a new growth of thin branches with few and still smaller leaves may partly replace them, while the rest of the bush develops the early symptoms of attack. In the second dry season most of the branches may die, but the rains again lead to the development of a few leafy shoots (fig. 8). The third dry season may see the bush killed, though it appears probable that several years often elapse before death takes place. This course is much slower than that of the other diseases described above except internal root disease, though the spread of infection from bush to bush is at least as quick, with the result that a considerable area may appear yellow and sickly even when the patches of dead bushes are of small size.

In certain areas the disease was said to be associated with the previous presence of particular trees, the commonest being *Parinarium mobola*. In one case seen nearly all the bare patches where bushes had been killed were situated so as each to encircle one of some half a dozen isolated, large, living *Albizzia fastigiata* trees, but the bushes between these were mostly in various stages of the disease and many were dead or dying.

In the early stage of attack the roots appear to be free from any fungous parasite. A complete examination of the root system from the collar to the finer feeding roots was carried out in several typical cases in the first year of the disease and nothing whatever was found that would explain their condition. The bark appears smooth and it and the wood are full of sap. They separate from one another unusually readily, appear to be more succulent, and the wood cuts more easily than in normal plants. The cells of the inner cortex and outer layers of the wood of the medium and smaller roots are often filled with a gummy substance together with flakes of a harder material. In the fleshy feeding roots the usual internal mycorrhiza of tea (the type with vesicles and arbuscules) is richly developed and the inner tissues are obviously healthy and functioning normally, but the surface of these roots and of those next in order may be irregular and roughened as if sucked or irritated by nematodes or something of the kind. A few roots were found, as might be expected, to contain occasional hyphæ, but these were not always of the same type and were altogether too few to account for a serious disease. Numerous attempted isolations from the roots gave quite inconclusive results, yielding no one fungus consistently and in some cases nothing at all. *Botryodiplodia theobromæ* was only once found in a single root, in these early cases, and it is impossible to attribute the disease to its attacks, though Captain Smee informed me that it is

common on bushes that have died in the manner described (which is very like certain cases attributed to this fungus) during the hot dry period of the year. Bushes killed by, or in the last stages of this disease that I examined showed various fungi in their roots including *Botryodiplodia*, but their general absence in the earlier stages makes it impossible to regard them as its cause.

The disease is locally regarded as a root disease and it is difficult to avoid this conclusion in view of the obviously spreading nature of the affected areas and their reported association with the previous presence of certain forest trees. Except for its unusually irregular spread, it has all the characters of a progressive underground infection by a parasitic fungus, though none such was found. The only other disease that I am acquainted with that spreads in a somewhat similar way and that apparently is not a root disease is the spike disease of sandal (*Santalum album*) in southern India, and this belongs to the most obscure group of the so-called virus diseases, a group of which peach yellows in the United States is the best known example. Though the upcurling of the leaf margins in affected tea bushes and their mottling with pale and darker green suggests a virus disease, I am not aware of any that spreads so gradually and continuously; the leaf mottling is only due to retention of colour by the veins longer than the rest of the leaf, being thus unlike that found in the mosaic diseases; and there is no accumulation of starch as in peach yellows and spike disease of sandal.

Virus diseases, with a few exceptions, are ordinarily transmitted from plant to plant by insects. The exceptions include tobacco mosaic, where human agency is probably responsible for most of the spread, and, perhaps peach yellows and sandal spike, where the method of transmission is unknown. In a few instances, the chief of which is raspberry mosaic, the insect vector may be so sluggish that spread is continuous from plant to plant mainly by passive dissemination of the insect (as by means of the wind or by persons passing through the bushes and conveying green fly from one to another on their clothing). Some such method of spread must be responsible if the tea disease here described is due to an insect-borne virus.

In the absence of knowledge of the cause of this disease it is difficult to suggest methods of control. Observations indicate that it is worst in gardens where the soil has been exposed to wash or where the bushes are enfeebled from any other cause. The general measures for the indirect control of root diseases by improving the vigour of the bushes discussed below should, therefore, have an effect in reducing the losses caused by this disease.. In advanced cases it is hopeless to attempt to save the bushes, and they should be removed and the patches treated as recommended for *Armillaria mellea* and *Ustulina zonata*. Whether earlier removal (as soon as the first symptoms are observed) should be recommended is doubtful on present knowledge. Experiments should be carried out in new extensions to test the effect of thorough roguing (eradication of every diseased bush at an early stage) on the spread of the disease, but such experiments shuld be under expert supervision if they are to yield reliable results. Stumping has been advised on account of the other diseases, and the reported association of this disease with certain tree stumps may indicate that this measure may be useful also against it.

There are many instances of successful control of a plant disease, the cause of which is unknown. Most of them are based on observations regarding the incidence and spread of the disease. Such information is very scanty in the present instance and requires to be supplemented by careful observation, pending an opportunity for more detailed research into the cause of trouble. It is not unlikely that the disease occurs in the East but has been confused with the effects of *Botryodiplodia theobromæ*, and it is hoped that the above description may call the attention of pathologists in other tea-growing countries to what is unquestionably one of the most serious diseases to which the tea bush is liable.

General Recommendations for Improving Root Development.

These should be directed primarily to checking soil wash, improving drainage, and maintaining soil fertility or restoring it when depleted.

The soils of the Mlanje tea area lend themselves particularly well to the checking of wash by the use of blind contour drains, the soil from which is thrown up along the upper face of the drain to make a low ridge which catches much of the silt and in time helps to form level terraces. Catch drains of this type were seen easily to hold the water in a fall of nearly nine inches in 24 hours, percolation in the open Mlanje soils being sufficient to prevent the drains from filling. In this case the slope was relatively gentle and the vertical distance between the drains was about 3½ feet. The various types of silt pits and terraces that may be used to check erosion are fully discussed by Captain Hornby in the Bulletin already referred to, and the details of their construction are outside my scope.

Cover cropping is the second main method of checking wash, and the extended use of cover crops in the Mlanje tea gardens, especially where there is little shade, would probably have a beneficial result. Little experimenting has been done in Nyasaland with cover crops suitable for tea, but many have been tested in Ceylon,[1] and some of those that have proved satisfactory there, especially species like *Indigofera endecaphylla*, belonging to genera common in the country, would probably be equally so under Nyasaland conditions. The period of the year when the cover is most required is December, as the first heavy rains, while the soil is bare after the hot weather and before the weeds have grown, do the greatest damage.

Green manuring and deeper cultivation have a two-fold effect in that they not only improve fertility but increase the water absorbing and holding capacity of the soil and thus check wash due to the run off of the surface water. A good many green manures have been tested,[2] but there appears still to be room for the introduction of low-growing leguminous crops that will keep down weeds, cover the soil well, and not impede the growth of the bushes. The "mposa" bean (*Phaseolus mungo*) was the most nearly satisfactory in this respect of those seen actually in use in the tea. In most gardens, however, green manuring is not practised, and its extended employment is probably one of the best methods of improving the surface development of the roots.[3]

Drainage is well known to improve root development and to lessen susceptibility to disease. The extended range of the root system in well drained soils helps the plant to resist drought conditions and to survive the loss of the surface roots from whatever cause, unless the taproot or collar of the bush becomes involved. Drainage and cultivation are the two main factors that render soil unsuitable for the growth of such forest fungi as *Armillaria mellea* and *Ustulina zonata*, and their neglect is probably the chief reason for the persistence of these parasites in gardens that have been cleared from forest for many years.

Fertilizers have been little used in Mlanje tea, under the mistaken belief that the soils are sufficiently rich to make them unnecessary. Whatever chemical analyses may show, there is sufficient evidence that the surface soils are, in general, in need of improvement, and in a great many gardens the use of fertilizers is clearly indicated. Phosphatic fertilizers combined with green manuring have a well-known effect in increasing surface root development and thus improving the health of the bushes. The Nyasaland Department of Agriculture is in a position to advise on the most suitable fertilizers for the different types of soil. In some of the gardens that have suffered most severely from soil wash there is no doubt that the restoration of fertility will be an exceedingly difficult task and will require to be carried out on the lines adopted for the renovation of old, worn-out tea soils in the East.

These matters have been touched on only in their bearing on the incidence of root diseases in the tea. Attention to them is at least as important as any direct methods of combating these diseases, such as stumping, trenching, and the removal of dead bushes. All the diseases encountered are present throughout the district, and the difference in their severity depends in great part on the manner in which the vigour of the bushes has been maintained. Neighbouring gardens may be seen, in one of which the losses from disease are relatively slight because the health of the bushes has been maintained by checking wash, fertilizing, and good soil and bush management, while in the other the condition of the tea has become so serious that it is doubtful whether it can be renovated without an almost prohibitive expenditure. There is probably no estate in the district which would not become as bad as the worst now visible in respect of root diseases if neglected, but, on the other hand, there are few that cannot be brought back into good condition by methods directed to remove the causes of ill-health discussed above.

Stem and Branch Canker (? Macrophoma theæ Speschnew).

The stem canker or die back associated with the presence of the fungus *Macrophoma theæ* is the only disease of consequence found on the above-ground parts of the bush in Nyasaland. It was first observed in February or March, 1926, when it caused much damage by killing back the shoots of the older bushes and leading to the death or serious injury of young plants and nursery seedlings. The attack was worst in hollows where the soil is moist and badly drained, and it was reported by Mr. E. W. Davy, Assistant Director of Agriculture (from whom the first specimens of the disease were received at the Imperial Bureau of Mycology), that there was no doubt that plants

1 *Cf.* Holland, T. H., in *Tropical Agriculturist*, LXVI, p. 248, 1926; LXVIII, p. 263, 1927.

2 Davy, E. W., "Crops for green manuring and soil protection."—Nyasaland Agric. Dept. Bull. 3, 1925.

3 *Cf.* Carpenter, P. H., "Green crops."—Quart. Journ. Indian Tea Assoc., 1926, part 4, pp. 170-175, 1926. The extensive literature on green manuring of arable crops in India is summarized by A. W. R. Joachim in *Tropical Agriculturist*, LXV, pp. 325-331, 1925.

raised from imported Indian seed were far less resistant to the stem canker than those from acclimatized Mlanje seed. Mr. Davy reported that Captain Smee had found a *Macrophoma* very commonly on the cankered areas, and the latter stated subsequently that this fungus was also found on *Grevillea* trees in the affected areas.

Isolations made from Mr. Davy's specimens yielded chiefly a species of *Macrophoma*, differing from *M. theicola* Petch, the cause of a stem canker in Ceylon, but agreeing in measurements with *M. theæ*, which Speschnew described as the agent of a leaf spot of tea in the Caucasus.[1] A species of *Tubercularia*, resembling that belonging to the *Nectria* that causes die back of tea in northern India, was also present on some of the branches. Cultures of both these fungi were taken to Nyasaland in order to attempt to produce the disease by inoculation.

During my visit this disease was little in evidence, no doubt as a result of the drastic treatment carried out during the previous year. One affected garden of young tea, however, had not been heavily pruned to eradicate the cankers, and in this a number of cases were seen. The affected bushes each had one or more withering branches with yellowed or falling leaves. When these branches were more closely examined they were found to show swollen cankerous areas (fig. 9) involving sometimes a considerable length of stem, sometimes only the neighbourhood of the lateral branches or the bases of the latter. The thickening surrounds the entire stem, as a rule, and its surface is marked by a longitudinal cracking of the bark, which is often detached in flakes. Through the cracks there may be a protrusion of reddish woody tissue, which forms irregular cushions so that the swelling is not of uniform thickness all round the stem. At the time of my visit (February-March) true cankers exposing the original wood were rare, the infections having evidently not progressed very far, but in the material collected by Mr. Davy the previous July typical cankers were not uncommon (fig. 10). When the shoot is entirely ringed and the bark is destroyed down to the wood, the branch dies back above the point of attack, and this die back of the shoots is the main symptom later in the year. The cankers are less regular in appearance than those caused in Ceylon by *M. theicola*, the callus ring surrounding them is less uniform and less prominent, and they are often partially covered by shreds of bark. They are, however, exceedingly like one of the forms of branch canker known on tea in India[2] without any clue having, as yet, been found as to its cause. Infection appears to take place just below the insertion of the lateral branches (possibly through the leaf scar) and to extend usually both up and down the main stem and also out along the lateral branch. The longer cankered areas are usually caused by the union of several distinct infections. The surface of the cankered area may show the small black pycnidia of *M. theæ* or less often, the light pink cushions of the *Tubercularia*. Other fungi are also found, but only one of these belongs to a genus (*Pestalozzia*) known to cause tumours or cankers, and as the species agreed with the common tea parasite *P. theæ*, which is not capable, so far as is known, of producing similar effects, it was not further considered.

The structure of the thickened stem tissues is of considerable interest. The greater part of the increased diameter is due to the formation of gall wood on the inside of the cambium. A much smaller increase takes place in the layers external to the latter, phloem and cortex. At a certain moment in the growth in thickness of the shoot, the cambium is stimulated to an excessive activity and commences to form on its inner face cells differing in their subsequent development from the normal elements of the wood. The new tissue thus formed is, therefore, heteroplastic, in Küster's sense of the word.[3] There is an increased production of parenchyma, the medullary rays are broader and less sharply defined, and the wood fibres and vessels may be few at first, as compared with the normal wood. The result is a kataplasmatic gall,[4] the bulk of the new tissue being gall wood. At the same time, there is a slight increase in the tissues external to the cambium ; these may become twice as thick as the normal bark, but the growth pressure exercised by the expanding gall wood causes splitting of the outer bark and the formation of irregular cork layers deeper in, so that finally there may be little cortex left. The expanding medullary rays may sometimes be traced across the cambium into the phloem, and in the latter, as well as in the deeper part of the cortex, stone cells and cells containing large crystals, almost entirely filling them, are developed.

1 Speschnew, N. N., "Die Pilzparasiten des Teestrauches."—Berlin, Friedländer, 1907, p. 17.

2 Butler, E. J., "Fungi and disease in plants."—Calcutta, 1918, p. 463, and fig. 24 on p. 83. The latter figure would pass equally well for the Nyasaland canker in a rather early stage.

3 Küster, E., "Pathologische Pflanzenanatomie," 3rd Ed., p. 344, 1925.

4 *Ibid.*, p. 187.

Sometimes the cambium is killed and the overlying cortex dies, the resulting wound being covered more or less completely by an overlapping growth of the gall wood and of tissues exterior to the latter. If only a small part of the cambium dies, and the surrounding tissues are growing rapidly, a fissure entirely closed in may be formed in a part of the ring between the normal and the gall wood. In severer injuries, and especially at a later period of the year, the wound remains as a gaping canker with swollen callus lips around it. No alteration ever seems to take place in the original woody cylinder until open cankers lead to its decay, and the pith of the stem is also unaltered in appearance.

As a result of the irregular growth of the gall wood, especially where fissures are produced, its elements do not pursue a regular radial course. The medullary rays and other radially disposed elements in the normal wood become laterally displaced or curved, and may even eventually lie transversely to the radial axis. A curious feature observed in some of the galls is that while the cells nearer the sound wood are mostly parenchymatous and relatively little differentiated though with strongly pitted or reticulated walls, those further out, near the cambium (and, therefore, the most recently formed), resemble normal wood with clearly differentiated fibres and vessels. In such cases it would appear that the stimulus that causes the development of the gall wood acts only for a time.

Colourless hyphæ occur in a few of the outer layers of the gall wood and in the phloem, in other words immediately on both sides of the cambium. In young galls, sections taken near the limit of the thickened part may show no hyphæ, even though the ring of gall wood is already clearly defined. In some galls no hyphæ were seen until nearly a quarter of an inch behind the part of the stem in which the new wood could first be distinguished. This suggests that the stimulus leading to the formation of gall wood acts beyond the limit of the area occupied by the fungus. The hyphæ found at the advancing edge of the infection were large "exploratory" hypæ, running longitudinally in the outermost vessels. Further back, more numerous, smaller hyphæ occur in the outer vessels, the neighbouring parenchyma, and the phloem tissues. They are always hyaline, intracellular, predominantly longitudinal in direction (except in the medullary rays), and sparingly branched. Sometimes even in fairly early stages, similar hyphæ can be found in the outermost vessels of the normal wood internal to the gall wood. At this period, however, hyphæ were not found in any other part, the pith, the cortex, and all the normal and gall wood except the regions above specified being quite free from infection. In older material, however, the mycelium spreads throughout all the tissues and is readily found from the cortex inwards to the pith.

There is little doubt that this mycelium is the cause of the disease. Its distribution, corresponding so exactly with the tissue stimulated to abnormal activity, and its constant presence a short distance behind the advancing limit of the stem thickening, tell strongly in favour of a causal connection. It is less certain that this mycelium is that of *Macrophoma theæ*. It has not been found possible to trace a direct union between the internal mycelium and the external pycnidia, and the single series of inoculation experiments undertaken with pure cultures failed, as did the similar ones made with the *Tubercularia*. A single failure, of course, is not conclusive, as there is no exact knowledge of the part of the stem through which entry is normally effected (leaf scar and wound inoculations on young branches were tried) nor of the season of the year at which the disease starts (the inoculations were made on 24th March, by which time the disease had already been in evidence for some months). It appears probable, on the whole, that *M. theæ* is the cause of the disease, not only because it was the fungus most commonly isolated from the cankers but also because *M. theicola* is already known to cause a somewhat similar disease while *M. tumefaciens* [1] forms tumours which are highly suggestive of a stimulatory action like that described above. In culture the mycelium of *M. theæ* would pass sufficiently for that present in the galls, except that with age the hyphæ become brown and brittle. In old cultures, too, the spores eventually become brown and septate, resembling those of the genus *Hendersonia*. Speschnew's fungus was found only on the leaves, and there are several cases in which species identified as *Macrophoma* have subsequently been found to develop septate spores when old, so that this fact by itself does not invalidate the identification of the Nyasaland fungus with the Caucasian one.

When the stem canker first appeared, Mr. Davy advised cutting the affected nursery seedlings back to three inches of stump, i.e. well below the cankered area, followed by heavy spraying with Bordeaux mixture and a subsequent lighter spraying when new growth commenced. On the young, recently planted out tea he recommended hard pruning, with spraying, and thorough draining of

1 Hubert, E. E., "A new Macrophoma on galls of *Populus trichocarpa*."—*Phytopath.*, V, pp. 182-185, 1915. Hyde, K. C., "Anatomy of a gall on *Populus trichocarpa*."—*Bot. Gaz.*, LXXIV, pp. 186-196, 1922.

the affected areas. In older gardens pruning out diseased branches was considered to be sufficient, accompanied by manuring. Further recommendations from the Bureau of Mycology included measures intended to promote improved root development and the application of potash. In affected nurseries attention has been drawn by Captain Smee to the necessity of improving soil conditions and, especially, the ventilation of the seedlings by opening up the vegetation surrounding the nursery site.

As already stated these measures, which were vigorously applied, appear to have been completely effective. In the absence of more exact knowledge of the life-history of the organism responsible for the disease they appear to be all that can be recommended.

2. Diseases of Tobacco in Nyasaland.

The climate and soils of a great part of Nyasaland are suitable for the growth of tobacco, the area of which under European management amounted to some 25,000 acres in 1927 with, perhaps, half as much in addition grown by the natives. The quality of the leaf is, in general, good and Nyasaland tobacco has found favour with the trade, so that, aided by imperial preference, there was a ready demand for the bumper crop that was being harvested during my visit. Both bright and dark tobacco are produced, amongst the varieties cultivated being the Rhodesian Hickory Pryor, Gold Leaf, White Burley, Melton, Western, etc.

Only a few of the tobacco plantations in the Shiré Highlands were visited owing to lack of time, so that it was not possible to attempt a survey of the most prevalent diseases, and the following notes are necessarily incomplete. It appears probable, however, that most or all of the tobacco diseases recorded in Southern Rhodesia and the Union of South Africa also occur in Nyasaland and that disease control will not differ materially in this large tobacco belt, allowance being made for seasonal differences in rainfall and the like. The first disease described below, however, has not been reported elsewhere in southern or eastern Africa, and its control will require to be worked out locally.

Black Stem Rot due to Pythium aphanidermatum.

A disease of tobacco seedlings was observed at Pusa, India, about 1916 and was found to be due to a species of *Pythium* to which the name *P. butleri* was given.[1] The same fungus caused a rot of ginger (*Zingiber officinalis*) rhizomes, which had been earlier attributed to *P. gracile*, and of the base of the stem of papaw (*Carica papaya*), cross-inoculations showing that it was able readily to pass from one host to another. Subsequently, strains of what appears to be the same organism were found attacking several cultivated cucurbits at Pusa.[2]

Some time earlier, in 1915, a similar fungus was described in the United States as a parasite of radishes and sugar beets, under the name *Rheosporangium aphanidermatus*[3] Later on, a root disease of sugar-cane caused by an organism which was identified as *P. butleri* was studied in Hawaii, and the suggestion was made that *R. aphanidermatus* was the same species.[4] This suggestion has been accepted by recent American workers and the name has been changed to *Pythium aphanidermatum*.[5] Diseases of various cucurbits, peas, and eggplants have since been found to be caused by it in America.

In 1922 a black stem rot or stem scorch of tobacco plants after transplanting was reported from Deli, Sumatra, where it caused so serious an outbreak in certain fields that scarcely a plant escaped.[6] Several species of *Pythium* were said to be able to cause it, one of these being at first named *P. butleri* and subsequently *P. aphanidermatum*.[7]

Specimens of a *Pythium* said to cause a tobacco disease were sent to me from the Gold Coast in 1923, and were identified as *P. aphanidermatum*,[8] the question of the distinction of this fungus from *P. butleri* being left over for comparative study, which has not hitherto been possible.

1 Subramaniam, L. S., "A Pythium disease of ginger, tobacco, and papaya."—*Mem. Dept. Agric. India*, Bot. Ser., X, 4, 1919.

2 Scientific Reports, Agricultural Research Institute, Pusa, 1924-5, pp. 52-53, 1925.

3 Edson, H. A., "*Rheosporangium aphanidermatus* a new . . . fungus parasitic on sugar beets and radishes."—Journ. Agric. Res., IV, pp. 279-291, 1915.

4 Carpenter, C. W., "Morphological studies of the Pythium-like fungi associated with root rot in Hawaii."—Bull. Exper. Stat. Hawaiian Sugar Planters' Assoc. Bot. Ser. III, pp. 59-65, 1921.

5 Fitzpatrick, H. M., "Generic concepts in the Pythiaceæ and Blastocladiaceæ."—*Mycologia*, XV, pp. 167-168, 1923.

6 Sidenius, E., "Verslag van het Deli Proefstation 1921-2."—Meded. Deli Proefstat. te Medan-Sumatra, Ser. 2, XXIV, p. 35, 1922.

7 Jochems, S. C., "Parasitaire stengelverbranding bij Deli-tabak." *ibid.*, XLIX, 1927.

Bunting, R. H., and Dade, H. A., "Gold Coast Plant Diseases."—London, Waterlow and Sons, pp. 87-88, 1924.

In Nyasaland a tobacco disease with the characters of the black stem rot of Sumatra was found by me in the Cholo, Mlanje, and Zomba districts. The fungus associated with it was indentified as *P. aphanidermatum*, and was quite similar to the published description of this species and also to the Gold Coast specimens, except in the oogonial and antheridial characters referred to below. In the most severe attack seen, the field had been cleared from forest the previous year, and the majority of the nearly mature plants that it contained at the time of my visit were wilting just as in a severe attack of root knot due to the nematode worm *Heterodera radicicola*. There was too little of the latter, however, to account for the diseased condition, and the owner had accordingly reported that his crop was attacked by an unfamiliar disease. In the Zomba district also the disease was recognized by planters as one not previously described in Nyasaland when first observed during the current year. Subsequently it was found in a couple of Mlanje plantations, and it may be presumed that it is present to some extent throughout the Shiré Highlands.

The disease causes a flaccid drooping of the leaves of the whole plant, most noticeable late in the day, the plants recovering to a certain extent during the night in the early stages. This wilting is unaccompanied at first by any browning of the leaves or upper part of the stem. As a rule, it is not very evident until the plants are nearly mature, but after topping, the symptoms rapidly develop. In the flowering stage, the flower stalk is the first to droop and soon falls over. In one affected area the plants were said to have never looked well after planting out, but this was attributed to the use of over-mature seedlings. In another, the leaf scars left after removing the basal leaves when transplanting showed a brown patch running down the stem; about three weeks after transplanting, a period of dry weather caused a check to the plants and though they came away again a certain number never grew normally and wilted when approaching maturity. In this instance also the trouble was traced back to the seed-beds, since three separate areas planted from the same nursery all developed the disease, others from different nurseries being less affected.

All the affected plants were marked by sunken black or dark brown areas at the base of the stem and extending for some inches above the soil level (fig. 11), several such patches sometimes being found on a single plant. The interior of the cortex ultimately becomes jet black under the sunken patches, which are due to a dry rot that causes the collapse of the cortical cells without, as a rule, any rupture of the epidermal layer. On splitting the stem the pith is also frequently blackened and usually is hollow and divided into chambers by transverse discs of tissue, the cavities being occupied by a loose growth of white, cottony mycelium. A similar mycelium may be found around the base of the stem, or can be developed by keeping the plants moist after pulling them up. The woody cylinder of the stem remains clean and white until it becomes invaded by secondary organisms. In a few cases infection was found to have spread from the stem into basal suckers, the leafy buds of which were blackened and rotted by the fungus.

A hyaline, unseptate, profusely branched mycelium occupies the cortex, the main hyphæ running between the cells and sending lateral branches into them. These intracellular branches tend to remain confined to the cells, which are often filled with coiled hyphæ, apparently unable to pass through the cell walls (fig. 12*c*). The wood is usually free from the fungus until a late stage in the disease. In the loose mycelial wefts found in the cavities of the pith or when an infected stem is incubated (occasionally also in the cortical mycelium) swollen, lobed or shortly branched hyphæ are common, or a normal hypha may bear lateral swollen buds or diverticula to a greater or less extent (fig. 12*a*). When placed in fresh water septa develop, cutting off a variable extent of hyphæ bearing these diverticula, the part thus cut off becoming a sporangium (fig. 12*b*). The sporangia are indistinguishable from ordinary hyphæ except that diverticula appear nearly always to be present where they form. They mature rapidly and discharge their undivided protoplasm, through an opening situated usually at the tip of one of the branches of a diverticulum, into a very fine bladder or vesicle, in which the zoospores are fashioned. As the latter develop they commence movement, at first in a mass and then individually, the vesicle soon rupturing to allow the separate zoospores to swim away. The earlier formed sporangia are small and contain up to fifty rather large zoospores of the type normal in the genus *Pythium*, but later on much larger ones, containing some hundreds of spores, may form. In these, especially, the contents of the hyphæ furthest away from the mouth may divide into masses representing individual zoospores before they reach the vesicle or even before they begin to move towards it, thus resembling the normal process of zoospore-formation in the genus *Aphanomyces*. Edson[1] had already noticed that cleavage into zoospores may occur before the contents of the sporangium escape into the vesicle.

[1] Edson, H. A., *loc. cit.*, p. 285.

Fig. 11.—Black stem rot of tobacco caused by *Pythium aphanidermatum*, showing sunken black patch at base of stem and drooping of the leaves.
(From a painting by Mrs. A. E. Shinn.)

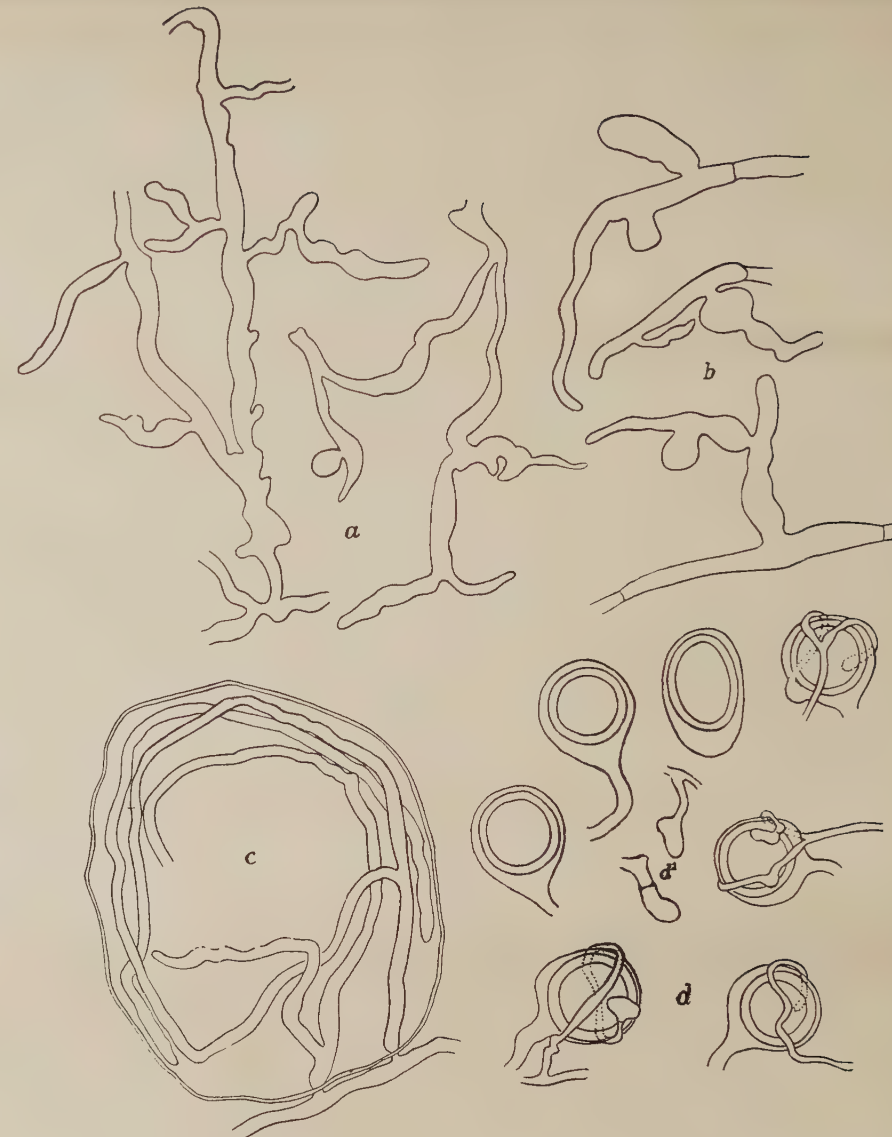

Fig. 12.—*Pythium aphanidermatum* from tobacco: *a*, Swollen mycelium from pith; *b*, sporangia; *c*, a pith cell with intracellular hythæ; *d*, cogonia, oospores and antheridia.

Oospores were found in the pith and surface mycelium on several occasions (fig. 12*d*). The oogonium is borne terminally on a hyphal branch and is irregularly club-shaped, measuring about 18 to 28 microns in diameter. It is fertilized by one or more antheridia borne on slender, coiled, often branched stalks which, in some cases at least, arise from a different hypha from that on which the oogonium is formed. The antheridial branches encircle the oogonium, usually nearly completely, before forming the terminal, rather small and irregularly shaped antheridium (fig. 12*d*1). The oospores lie loosely within the oogonium and are usually quite spherical, though sometimes elongated to fit the shape of the host cells. They are colourless, average 18 microns in diameter, (extremes 14.5 to 24 microns), and their wall is usually 3 to 3.5 microns thick. In its oogonial and especially, antheridial characters the fungus agrees more closely with that described by Carpenter on sugar-cane in Hawaii than with the original descriptions of *P. aphanidermatum* and *P. butleri*, but until more is known of this group of parasitic forms it seems unnecessary to give it a distinct name.

The description of tobacco stem scorch in Sumatra, the only other locality besides the Gold Coast and Nyasaland in which *P. aphanidermatum* has been reported causing a disease of tobacco after transplanting, corresponds fairly closely to that given above. In its most typical form it is said to appear soon after planting out, but infection may occur from this period up to a few days after full growth. Seedling infection has been occasionally seen and may involve the leaves as well as the stems. Infected young plants have their stems much shrunken near the ground level on account of a rot which may cause the plants to break or fall over. When more woody, the stem shrinkage is restricted to the cortex, and results in a sinking in of the stem in a broad patch, often confined to one side. In mild cases there may be only a few dark stripes on the stem. When cut, the cortical tissues of affected parts appear jet black. The hollowing and chambering of the pith are as described above, and a white, loose, woolly growth of mycelium is often found around the stem below ground level.

The worst attacks in Sumatra have been on land planted with *Leucaena glauca*, which is sometimes grown to protect the secondary jungle in fallow tobacco land from fire. Both this plant and *Phytolacca decandra*, also sometimes found in tobacco land, have been shown to be susceptible to infection and to transmit the disease to the tobacco crop. Infection is especially liable to occur when transplanting is done during wet weather; after dry weather during the period of transplanting little stem scorch appears. All types of soil are liable to infection, but the worst attacks appear to be in clay soils containing an admixture of sand. In the Gold Coast the disease occurs in hot, dry savannah land which is liable to waterlogging during the rains and becomes caked when dry. Tobacco growing on better soil in the neighbourhood escaped.

As the parasite belongs to the fungi that require films of free water for their dissemination, and as there is evidence that infection starts in the seed-beds, the chief preventive measures that can be recommended at present are to reduce watering and to allow the soil to dry somewhat immediately the first cases are seen in the nursery. At the same time the ventilation should be improved by raising the shade or removing it at night, and this will also help to dry the beds. Little can be done to check the disease after transplanting, except the removal of infected plants and their destruction by burning in order to prevent the carrying over of the disease to the following season. The oospores alone are capable of prolonged vitality, and as they are chiefly formed in the pith the destruction of affected plants should kill most of them. In Sumatra it is recommended that special seed-beds should be kept in areas subject to the disease, to provide supplies for replacing plants killed by it in the first few days after transplanting, when most of the attacks occur. These beds should not be watered for some days before their seedlings are required, in order to get more woody plants, and should be sown a few days earlier, so that the seedlings will be older by, say, five days than those normally used. Instead of having special seed-beds, it is sometimes enough to leave some seedlings behind when transplanting from the ordinary beds and to cease watering these for eight days or so before they are used. It is also advised to be careful, when planting out, not to bury the stem in the soil, since it is more susceptible to attack than the roots. The seedlings are placed in shallow holes with a little loose soil around the roots, and only watered sufficiently to secure growth, and then, eight or ten days later, the holes are filled and the soil drawn up around the plants. Most of the Sumatra attacks appear to be due to infection after transplanting, and they are so frequently associated with the previous presence of *Leucaena glauca* or, less often, *Phytolacca decandra* that the best remedy is said to be the eradication of these plants. The prevalence of *P. aphanidermatum* in Nyasaland is a strong argument against the introduction of *Leucaena glauca* as a green manure, but whether there are any other indigenous plants liable to attack by this fungus is not known.

Leaf Spots.

Tobacco suffers rather severely from various leaf-spotting diseases in Nyasaland. The commonest of these during the period of my visit was the so-called frog-eye spot, due to *Cercospora nicotianæ*. This is found chiefly on leaves that have become mature, and is thus ordinarily confined to the basal and middle parts of the plant. When the harvest is delayed a large proportion of the leaves may become infected. The bumper crop of 1927 was no doubt responsible for the many complaints of leaf injury from this fungus in the curing barns, as the labour force was not always sufficient to cope with the crop and a good deal of it was cut late. Under such conditions, even when the harvested leaves look fairly clean, a number of incipient infections are likely to have occurred before the leaves are cut, and these will continue to develop for some time in the barns. On several occasions a large proportion of the leaves in the barns was found to be badly spotted, the spots varying from the ordinary small, circumscribed ones, to large spreading patches which ultimately invaded a great part of the leaf. Unlike the spots formed in the field, most of which have a pale centre surrounded by a narrow brown line, the barn spots were uniformly dark in colour, with little or no zoning. Most of these spots remain without producing spores unless the leaf is taken out and incubated in a saturated atmosphere, when in two or three days a very copious growth of long conidiophores and conidia takes place. At first sight the fungus concerned is difficult to identify with *C. nicotianæ*, the conidiophores being very long (up to over 500 by 6 microns), unbranched, multiseptate, with few knee bends, and bearing very large conidia (up to over 300 by 4.5 microns at the base) at their apices. The knee bends are due to a further growth of the conidiophore from below the terminal conidium, the latter being pushed over to one side and soon falling off, while another terminal conidium develops at the apex of the branch. This long-spored form was first found in the Dutch East Indies and subsequently considered to be a distinct species, *C. raciborskii*. More recent workers in India, Ceylon, and the Dutch Indies, however, regard it as only a form of the American frog-eye organism, *C. nicotianæ*, and in these countries as well as in Rhodesia the latter is the name used.

A second barn spot of different appearance was seen in a few plantations, causing much damage. The spots were intensely black, often slightly raised and rough on the surface, small, and irregular in shape. At first they were taken for angular leaf spot (*Bacterium angulatum*), but in every case examined the superficial tissues were found to contain large quantities of dark, brittle hyphæ, often aggregated into stromatic masses, and responsible for the slightly raised surface of the spots. On incubation these spots gave the same *Cercospora* fructifications as those mentioned above. In some cases it was almost or quite impossible to detect these spots before the tobacco was put in the curing barns, though they were usually visible on holding the leaf up to the light as very fine points of lighter green than the rest of the tissues. It is possible that their subsequent development in a form so unlike that normally produced by *C. nicotianæ* is due to the special conditions of temperature and the like in the barns. Further work, however, is required before it can be concluded that all the spots that develop or spread in the barns are due to this fungus, though all those examined by me appeared to be associated with it. As a barn spot, under the conditions of the 1927 harvest, this disease is more destructive than in the field.

C. nicotianæ is a true parasite and, like most of the genus, not very easy to grow on dead materials, though able to retain its vitality for a considerable period on the withered leaves, after ceasing growth. Hence the method adopted locally to check its extension in the barns by raising the temperature to 120° F. or more, for a time, a method that is said to have given good results in many cases, probably acts rather by killing the leaf tissues than by injuring the fungus, which the temperature reached would be quite unlikely to do. If the leaf is killed too quickly, however, the curing process is apt to suffer, and great care has to be exercised or the remedy proves worse than the disease. Undoubtedly the chief way to avoid an excessive amount of spotting in the barns (a little is of no account) is to harvest the leaves before they are over-ripe. An additional precaution is to remove the affected basal leaves as they develop the spots and before the latter have time to produce spores which will infect leaves higher up. A Florida report states that frog-eye was very prevalent in the fields in 1922, but that where the leaves could be primed early little damage was caused. In Java, where the barn spot caused by this fungus has also been reported[1] rapid drying and improving the ventilation of the barns have given good results. It is probable that, as a field disease alone, this fungus is not ordinarily capable of causing enough injury to justify special measures of control, but it is a serious trouble in the curing barns, and the recommendations given above should be of value in preventing it from reaching the barns and checking its extension in the latter.

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1 Jensen, H., "Ziekten van de tabak in de Vorstenlanden."—Meded. Proefstat. Vorstenl. Tabak, XL, pp. 17-19, 1. 12, 1921.

Other tobacco leaf spots observed were associated with *Alternaria* sp. and *Phyllosticta nicotiana*, but they were of minor importance and usually associated with injury to the leaves during high winds or the like.

Both wildfire (*Bacteriam tabacum*) and angular leaf spot (*Bact. angulatum*) have been reported to occur in Nyasaland, and in a few cases spots were found that were probably due to one or other of these diseases. At the time of my visit, however, the tobacco was too far advanced for much evidence of the damage caused by them to be visible, and I was informed that neither had been prevalent in the current year's crop. Their characters and control are too well known to require description, but they are not always easy to distinguish from one another without careful microscopical and cultural examination. Work on these diseases is in progress in the neighbouring colony of Southern Rhodesia and the results will, doubtless, be applicable in the main under Nyasaland conditions.

Powdery mildew (*Oidium tabaci* or *Erysiphe cichoracearum*) was rather prevalent on some estates and is possibly gaining ground since the popularity of the Hickory Pryor variety has led to its extended cultivation. This variety is moderately susceptible and has replaced certain less susceptible varieties previously grown. As in other countries, the disease is worst in shady places and is associated with certain climatic conditions, including periods of hot dry weather. A careful watch should be kept on its spread, as it is scarcely possible to control it in any other way than by the growing of resistant varieties. Susceptibility to mildew cannot be judged by a single season's observation, but if infection is found to increase during a period of years, search should be made for resistant strains of Hickory Pryor or other suitable varieties to replace those now grown.

The disease is well known throughout southern and eastern Africa and in the East. In Java it has become of considerable importance, and serious efforts have been made to find a satisfactory method of control.[1] The only direct treatment that has given good results without injuring the curing properties of the tobacco is the application to the soil under the crop of sulphur at the rate of 150 lb. to the acre. This is far too costly to be practicable under Nyasaland conditions. In the early stages, the spread of infection may be checked to some extent by removing the first leaves that show the mildew. Wide spacing and free ventilation also help to reduce the severity of the attack.

Non-Parasitic Leaf Spots.

Various types of non-parasitic leaf spots are common on tobacco in Nyasaland, as in other countries. The most noticeable is the white speck, white rust, or pox disease, characterized by the development of large numbers of small, irregular, slightly sunken, white spots on the leaves. These may be confused with one form of the spotting caused by *Cercospora nicotianæ*, but in the latter the white spots are round and bounded by a narrow brown line, and they are seldom so small or so densely crowded as in the white speck disease. The latter also is found on leaves of all ages, instead of being, as a rule, confined to the middle and lower leaves of the plant.

Another type of spotting is that commonly known as red rust, of which there appear to be several forms. One of these, prevalent in Rhodesia and South Africa, in said to be caused by the fungus *Macrosporium longipes*, but most of the red rust seen in Nyasaland was not associated with any obvious parasite.

Both white speck and red rust are believed to be non-infectious and they usually affect only individual leaves or plants, not spreading from plant to plant. They, therefore, cause relatively little damage as a rule. Their cause is unknown and no methods of control have been described.

Virus Diseases.

Tobacco mosaic is at least as common in Nyasaland as in any other tobacco-growing country. Late in the season, after harvesting has been in progress for some time, it is usual to find practically every plant with mosaic symptoms in the lateral shoots and suckers that develop during this period. Fortunately, much of the infection is late in developing, and the yield and quality are not so seriously affected by the disease as might be expected. It is well known to all planters and it would appear that care is usually taken not to plant out mosaic infected seedling from the seed-bed. No method of controlling the disease in the field is known, and much work yet remains to be done on the means by which the disease is carried over from one season to the next in Nyasaland before any serious effort to check it can be made.

1 D'Angremond, A., "Nadere gegevens over bestrijding van veldschimmel, etc."—Meded Proefstat. Vorstenl. Tabak, LVI, 1926 (English summary).

A second disease of the same group, which is relatively common in Nyasaland, is that variously known in other countries as ringspot, ringworm, or hieroglyphics. It was first described in Virginia but has also been found in other parts of North America,[1] in Sumatra,[2] and probably in South Africa.[3] That it is an infectious disease was conclusively established in 1927, when it was found to be readily transmissible from diseased to healthy plants by inoculation with the crushed leaf tissue, just as in tobacco mosaic. As no parasite has been found, it is regarded as one of the transmissible virus diseases, but with limited powers of dissemination so that natural spread from plant to plant is not marked.

Affected leaves are marked by white or pale rings or wavy lines, which often bear a definite relation to the veins, spreading out on each side of the latter in leaf-like patterns. The number of affected leaves on a plant and also the area of the leaf marked by the wavy lines vary greatly, but usually only a relatively small part of a few leaves is attacked. The effect on the leaf differs according to the variety of tobacco; in some there is nothing more than the often rather faint outline caused by the pale wavy lines, while in others the part of the leaf within the line turns brown and dries up. What is possibly only a form of the same disease is a brown decay of the veins on part of the leaf, which does not spread much into the surrounding tissue, but may lead to distortion and cause a good deal of injury at harvest time. On the whole, however, ringspot is not a serious disease, and it is only mentioned because it is one with which most planters are familiar so that what little is known about it is of interest.

The above notes cover all the tobacco diseases that were seen. None of them approaches in importance the root-knot disease caused by the worm *Heterodera radicicola*, which is by far the most serious tobacco trouble in Nyasaland. Some evidence was obtained that both the Granville wilt or slime disease due to *Bacterium solanacearum*, and the black root disease caused by *Thielavia basicola* occur in Nyasaland, but no serious attacks that could be attributed to them, or to the equally destructive *Fusarium* wilt of other countries, were seen.

1 Fromme, F. D., Wingard, S. A., and Priorde, C. N., "Ringspot of tobacco: an infectious disease of unknown cause."—*Phytopath.*, XVII, pp. 321-328, 1927.

2 Jochems, S. C. J., "Handleiding voor de herkenning en bestrijding van de ziekten van Deli-tabak."—Meded. Deli Proefstat. te Medan-Sumatra, 2nd Ser., XLIII, pp. 30-31, pl. 27, 1926.

3 Moore, E. S., "Diseases of Virginian tobacco in South Africa."—Journ. Dept. of Agric. S. Africa, XII, p. 454, fig. 20, 1926.